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OPERATIONAL EFFECTS ON CRASHWORTHY SEAT ATTENUATORS

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AVIATION APPLIED TECHNOLOGY DIRECTORATE POSITION STATEMENT

This report documents an investigation of the performance of first-generation crashworthy seat attenuators used to absorb crash loads in U.S. Army aircraft. Aging and environmental effects on these devices are determined by inspection and test. The contractor's approach to evaluation of energy attenuators is considered valid and is concurred with. Results of this contract will be considered in formulating future programs, aircraft design requirements, and field maintenance requirements, if necessary.

Kent F. Smith of the Aeronautical Systems and Technology Division served as project engineer for this effort.

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13. ABSTRACT *(Maximum 200 words)*
Energy absorbers were removed from crashworthy crew and troop seats aboard UH-60A Black Hawk helicopters which had been in service for up to nine years. The fielded energy absorbers were tested both statically and dynamically and the load-deflection characteristics were compared to new energy absorbers to determine the operational effects. There were three energy absorber types tested: inversion tube, rolling torus, and wire bender. Seat systems with energy absorbers not meeting the manufacturer's specified load-deflection characteristics were modeled by computer simulation to determine the change in injury potential in a vertical crash scenario. In general, the inversion tube and rolling torus energy absorbers' performance did not change as compared to new attenuators. The wire benders, however, had a failure rate of 48 percent which appeared to be fatigue related.

(JG)

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1.0 INTRODUCTION

The UH-60A Black Hawk is the Army's first helicopter equipped with crashworthy (energy-absorbing) seats for all aircraft occupants. These seats absorb ground impact vertical energy by stroking downward relative to the aircraft floor at a load which is preset to approach the upper limit of human spinal compressive tolerance.

Three different designs of seat energy absorbers are employed in fielded UH-60A helicopters. UH-60A's have been in service for approximately 10 years, yet the long-term environmental degradation effects on the various energy absorbers was not known. It is important that these devices maintain their design load-deflection properties during the period they are in service to ensure their performance should a mishap occur.

During this program, crashworthy seat energy absorbers were selectively removed from high time UH-60A aircraft which have seen service under a wide variety of environmental conditions. The energy absorbers were subjected to static and dynamic stroking in a test rig with their load-deflection properties measured and compared to those of new energy absorbers. Conclusions were made regarding the effects of aging, and occupant injury implications should the aircraft crash. Recommendations for future field actions are also presented.

2.0 PROGRAM SUMMARY

The energy absorber program was divided into four tasks.

2.1 TASK I - ENERGY ABSORBER CHANGE OUT

Energy absorbers were removed from crashworthy crew and troop seats aboard 12 Government-selected UH-60A Black Hawk helicopters and replaced with new Government-furnished energy absorbers. Government selection was based on criteria which combined the environmental effects of aircraft age and flying hours. Five selected aircraft were equipped with pilot/copilot seats of the Simula/Norton design, five with the Aerospace Research Associates, Inc. (ARA) design, and two with the Sikorsky Aircraft troop seats.

Each crew seat energy absorber was identified by aircraft tail number and specific seat location (pilot or copilot) and serial number. The troop seat energy absorbers were identified by aircraft tail number and grouped in pairs for each seat. Operational history was also documented for each aircraft based on the information supplied by the user.

2.2 TASK II - FIELDED ENERGY ABSORBER INSPECTION AND TESTING

The energy absorbers were visually inspected and outward signs of deterioration and/or damage were documented. The length of each energy absorber was measured to see if stroking had occurred due to hard landings, seat damage, etc. The energy absorbers were then subjected to static and dynamic testing to establish load-versus-deflection curves for each unit. A one-seat set of crew seat energy absorbers (two for Simula/Norton, six for ARA) and a two-seat set of troop seat energy absorbers underwent static testing. The remaining energy absorbers were subjected to dynamic tests designed to simulate actual crashes with a deflection rate to achieve the full design stroke within 150 msec. After each test, static or dynamic, all energy absorbers were closely inspected for deterioration or damage not apparent during the pretest inspection.

2.3 TASK III - NEW ENERGY ABSORBER TESTING

Newly manufactured Government-furnished energy absorbers of each type were tested. They were subjected to the same static and dynamic tests described in Section 2.2 for Task II. The number of samples for static tests was the same as for Task II. For dynamic tests, three seat sets each of crew seat and troop seat energy absorbers were tested.

2.4 TASK IV - DATA ANALYSIS

In this document, the results of all static and dynamic tests are presented in the form of load-versus-deflection curves. These load-versus-deflection curves were integrated to obtain total energy absorption. Differences in mean stroking load and total energy absorption between fielded and new energy absorbers are fully documented. Computer program SOM-LA (Seat/Occupant Model - Light Aircraft) was used to evaluate the injury potential for seats based on the results of Task II.

3.0 SCOPE OF TESTING

In-service energy absorbers were inspected and then tested either statically or dynamically. New energy absorbers were tested in the same manner. The sample of in-service energy absorbers totaled 20 Simula/Norton, 60 ARA, and 48 Sikorsky. The quantity of new test units for the Simula/Norton, ARA, and troop seats were 8, 24, and 10, respectively. Table 1 summarizes the testing.

TABLE 1. ENERGY ABSORBER TEST MATRIX

	Simula/Norton Energy Absorber Tests		ARA Energy Absorber Tests		Troop Seat Energy Absorber Tests	
Type of Unit	Static	Dynamic	Static	Dynamic	Static	Dynamic
In-Service Units	2	18	6	54	4	44
New Units	2	6	6	18	4	6
Total	4	24	12	72	8	50

Total energy absorbers tested: 170

4.0 SEAT DESCRIPTIONS

4.1 TROOP SEAT

The ceiling-mounted Sikorsky troop seat is a lightweight unit consisting of fabric stretched over an aluminum tube frame and is capable of being positioned to face in the forward, aft, or lateral direction. Energy is absorbed by bending and unbending wire as it passes over rollers during the stroking operation. Two wire benders are packaged within the frame upright tubes and two inside the lower diagonal struts. See Figure 1 for an illustration of the troop seat and energy absorber. Only the two overhead wire benders were tested as they are the most critical in determining the seat occupant's injury potential.

4.2 ARA CREW SEAT

An armored bucket is attached to the upright steel frame through a system of six rolling torus energy absorbers (Figure 2). Each rolling torus energy absorber stage consists of a single layer coil of wire captured in the annular space between two cylinders. The radial clearance between the concentric cylinders is dimensioned and toleranced so that the wire is squeezed to create the necessary friction force to roll when the two cylinders move relative to each other. The upper and middle seat energy absorbers are multistage with stroking load dependent on stroking distance.

The stroking of the seat bucket is not guided and allows the bucket to move in a manner so as to somewhat "self-align" with the input crash pulse and react, to a degree, along all axes.

4.3 SIMULA/NORTON CREW SEAT

The Simula/Norton armored bucket is attached to a semi-rigid frame with four roller bearings, as shown in Figure 3. The seat is allowed to stroke only in the vertical direction in a guided path. Two inversion tube energy absorbers are attached between the frame upper crossmember and at the vertical adjustment mechanism attached to the seat bucket back. Vertical inertial loads force the seat bucket down the guide tubes against the resistance of the energy absorbers, producing an energy-absorbing stroke in that direction. The tensile, inversion tube energy absorbers used on this seat use the force required to invert (to turn inside out) a length of aluminum tubing enclosed in an outer housing to absorb crash energy.

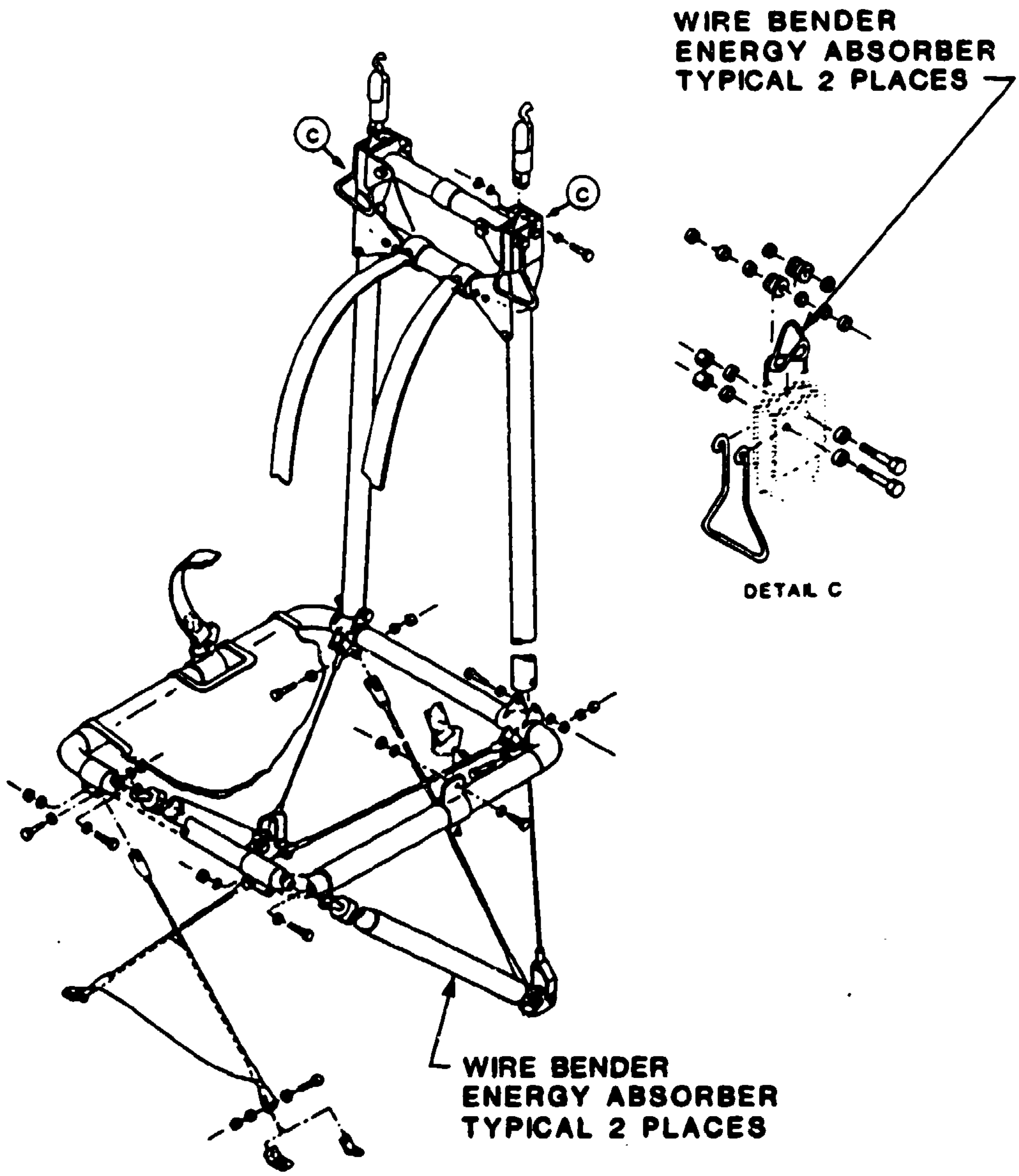


FIGURE 1. SIKORSKY TROOP SEAT AND ENERGY ABSORBER.

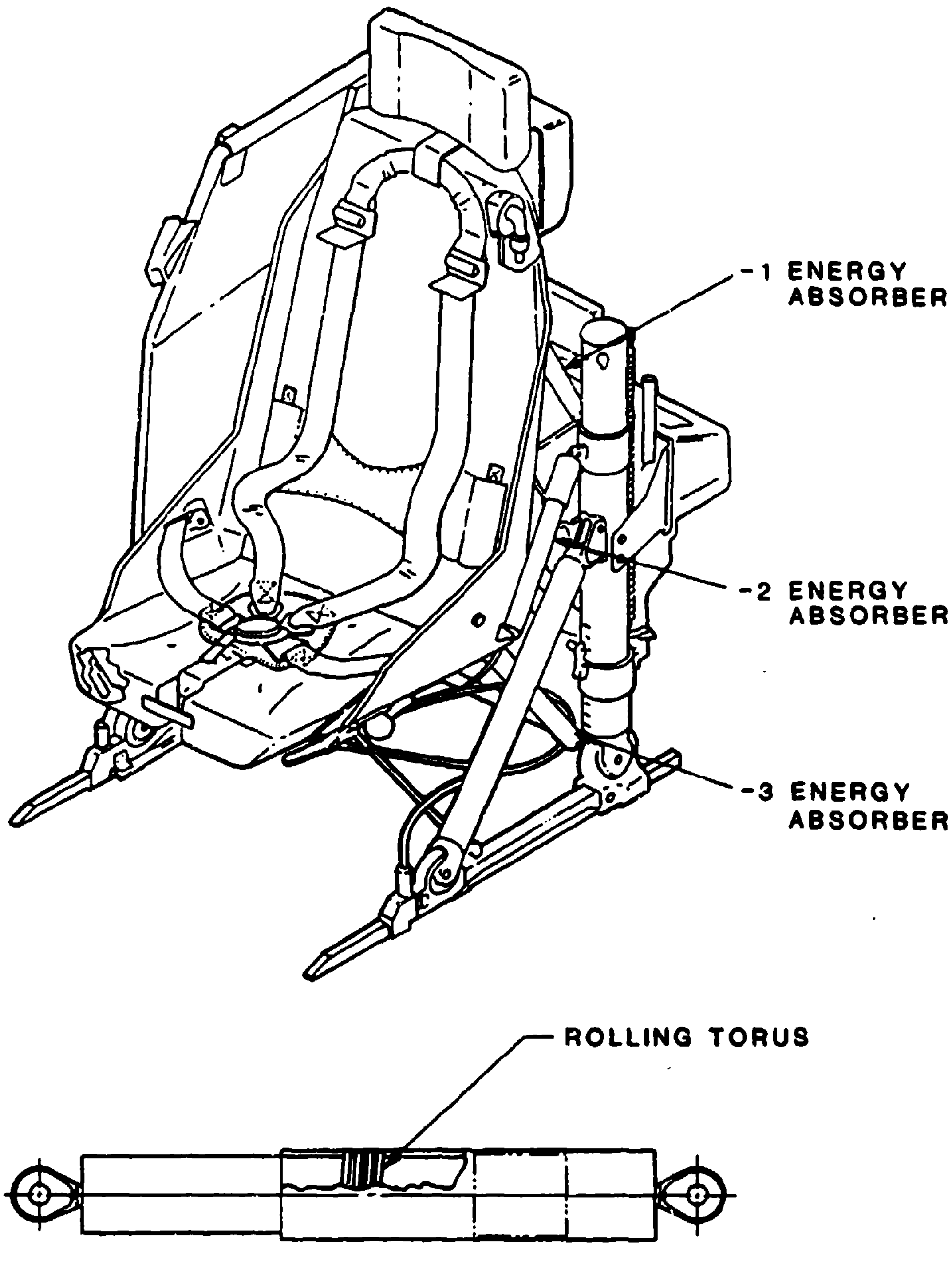


FIGURE 2. ARA CREW SEAT AND ENERGY ABSORBER.

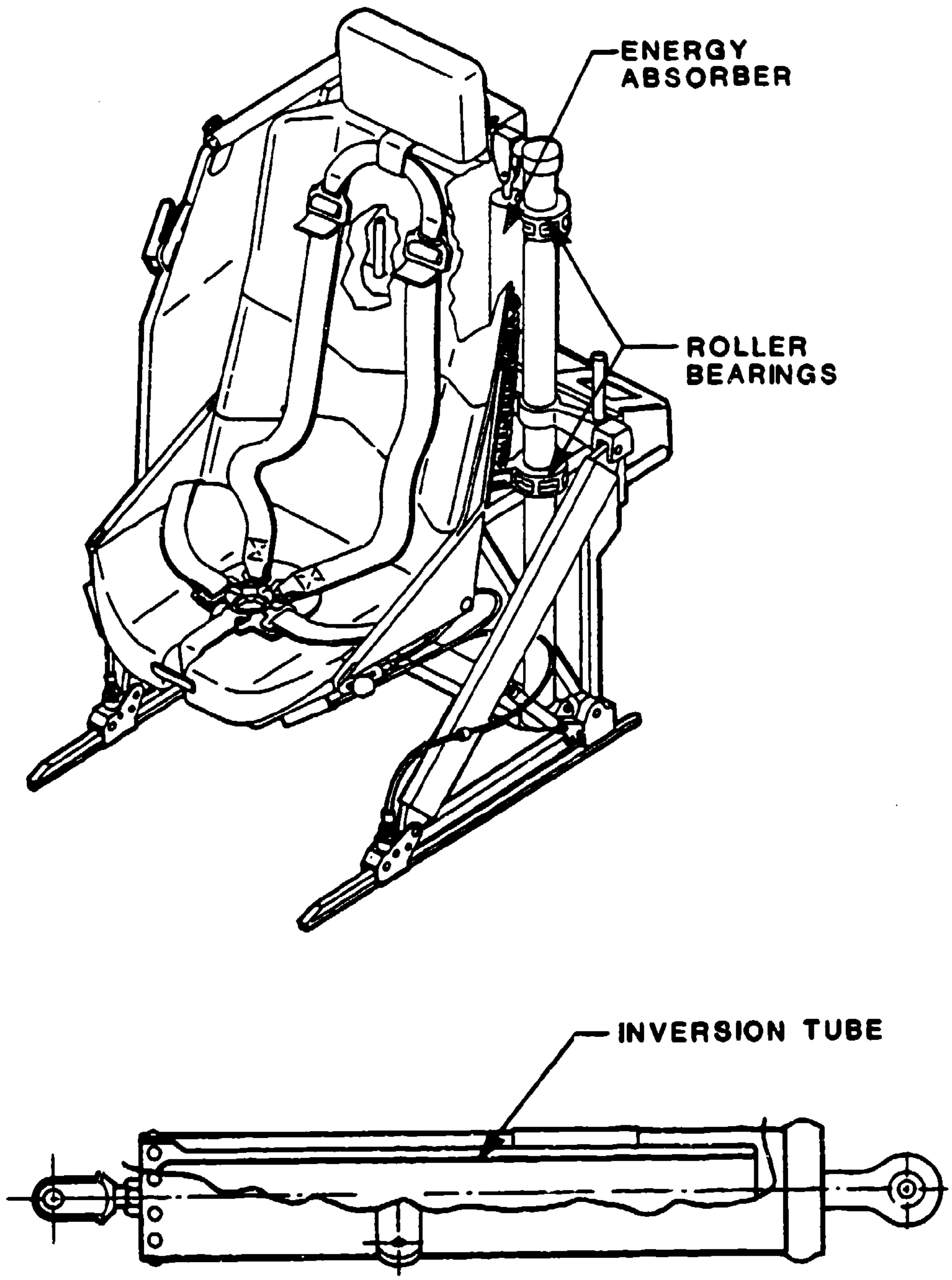


FIGURE 3. SIMULA/NORTON CREW SEAT AND ENERGY ABSORBER.

5.0 ENERGY ABSORBER CHANGE OUT AND INSPECTION

5.1 AIRCRAFT SELECTION

Tables 2 through 4 summarize data pertinent to energy absorber selection, including aircraft identification, seat and energy absorber identification, aircraft delivery date, and number of flight hours.

TABLE 2. SIKORSKY TROOP SEAT ENERGY ABSORBERS

Aircraft Tail No.	Aircraft Delivery Date	Flight Time (hr)
77-22720	5-79	2,261
78-22971	10-79	1,200

The wire bender energy absorbers do not have serial numbers.

TABLE 3. ARA CREW SEAT ENERGY ABSORBERS

Aircraft Tail No.	Aircraft Delivery Date	Flight Time (hr)	Seat S/N	Energy Absorber S/N Top (-1)	Middle (-2)	Bottom (-3)
81-23597	7-82	873	031	103/095	106/091	106/101
			*	114/099	086/097	114/095
81-23598	7-82	998	043	140/101	114/109	094/083
			042	120/017	088/107	092/001
81-23601	7-82	1,032	046	137/118	102/072	079/103
			045	142/145	112/101	098/089
81-23619	9-82	1,304	081	208/215	163/158	172/174
			077	216/209	195/188	168/179
82-23678	11-82	1,129	126	310/311	259/262	278/279
			128	316/321	265/268	280/281

*Nameplate placard missing.

TABLE 4. SIMULA/NORTON CREW SEAT ENERGY ABSORBERS

Aircraft Tail No.	Aircraft Delivery Date	Flight Time (hr)	Seat S/N	Energy Absorber S/N
77-22728	7-79	1,535	004	0013/0014
			012	0046/0047
78-22966	8-79	1,505	035	0143/0142
			066	0188/1516
78-22973	12-79	1,764	083	0225/0224
			082	0203/0204
78-22990	12-79	1,672	118	0297/0296
			*	0283/0282
78-22991	1-80	1,723	120	0287/0286
			064	0168/0167

*Nameplate placard missing.

5.2 PRETEST INSPECTION RESULTS

Pretest inspection of the energy absorbers revealed no evidence of field tampering, stroking, degradation, or misuse. The general seat environment and energy absorber condition were documented on data sheets at the time of energy absorber removal from the aircraft. Replications of the data sheets are included in Appendix A. ARA energy absorbers generally had small amounts of oil seepage. The troop seat energy absorbers had slight surface discoloration. The measured lengths of each energy absorber are tabulated in Appendix A.

The aircraft maintenance histories did not indicate any energy absorber replacement, so it was assumed that they were the originals supplied. The energy absorber serial numbers were consistent with the seat serial numbers except for Simula/Norton seat S/N 066, which had energy absorber S/N 188 and S/N 1516. Apparently, the S/N 1516 energy absorber was a replacement.

6.0 ENERGY ABSORBER TEST PROCEDURES

6.1 STATIC TESTING

The energy absorbers selected for static testing were mounted in a frame similar to that illustrated in Figure 4. A load cell was mounted between the bottom of the energy absorber and the hydraulic cylinder to measure the force applied to the energy absorber as it stroked, and a displacement transducer measured the amount of stroke. Load was applied to the energy absorber by a hydraulic cylinder sufficient to stroke it at a constant rate not to exceed 2 in./min. The energy absorbers were stroked to their design limits.

The Simula/Norton and ARA energy absorbers were mounted to the test frame by simple clevis attachments since both ends of the energy absorbers have rod ends. The troop seat wire-bending devices required a fixture, as shown in Figure 5, which was fabricated from a production seat frame to ensure that proper roller spacing and wire guidance was provided.

6.2 DYNAMIC TESTING

The remaining energy absorbers that were not tested statically were subjected to dynamic testing in the apparatus depicted in Figure 6. The apparatus consisted of a drop cage that was subjected to rapid downward acceleration through the use of a hydraulic cylinder charged with an accumulator. When the drop cage impacted the sand bed, deceleration occurred and the test frame/weight assembly continued to travel downward on the guide tubes, causing the energy absorber to stroke.

Instrumentation measured the stroking force of the energy absorber, the acceleration of the moving part of the fixture, and the displacement of one end of the energy absorber relative to the fixed end. The test was performed so the design stroking limit was achieved below 150 msec. Mounting fixtures similar to those used on the energy absorbers during static testing were used during dynamic testing.

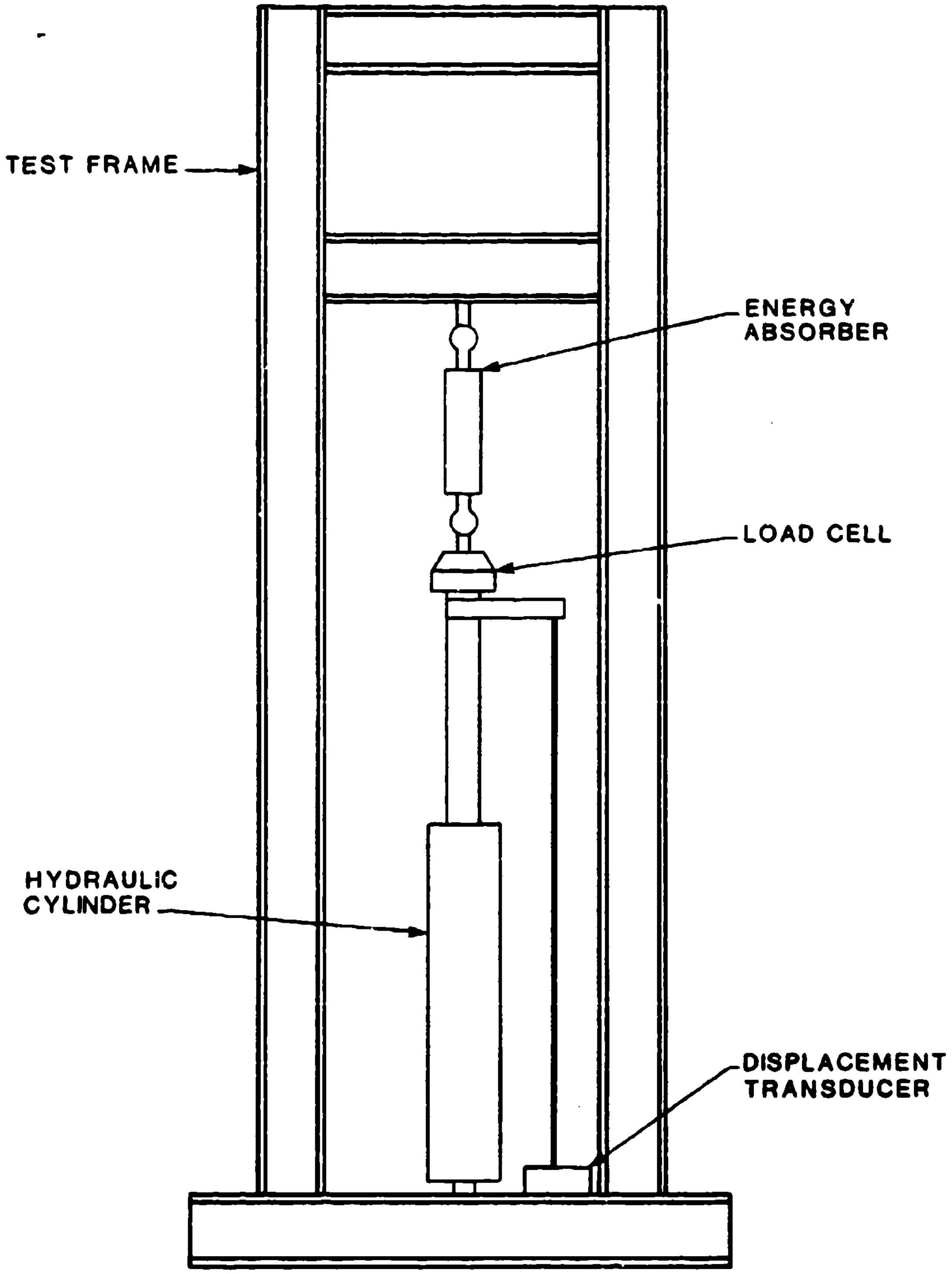


FIGURE 4. ENERGY ABSORBER STATIC TEST APPARATUS.

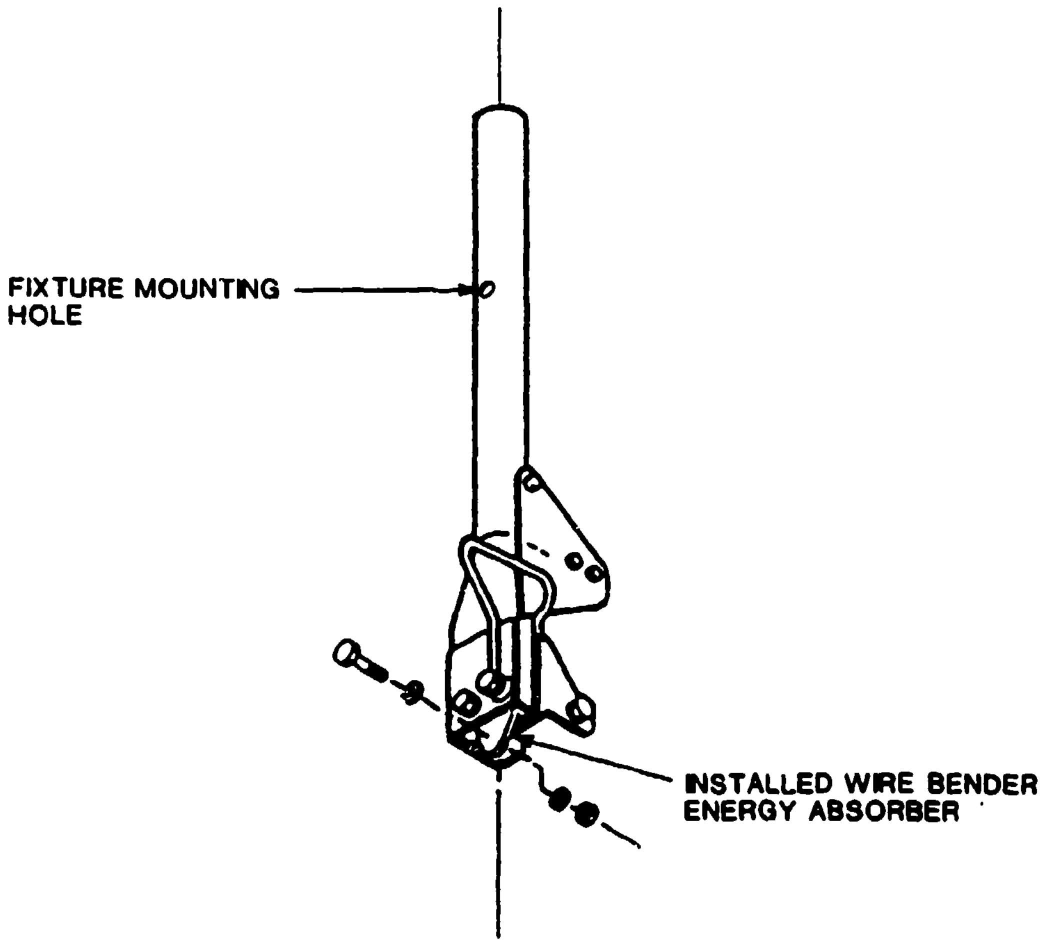


FIGURE 5. TROOP SEAT ENERGY ABSORBER TEST FIXTURE.

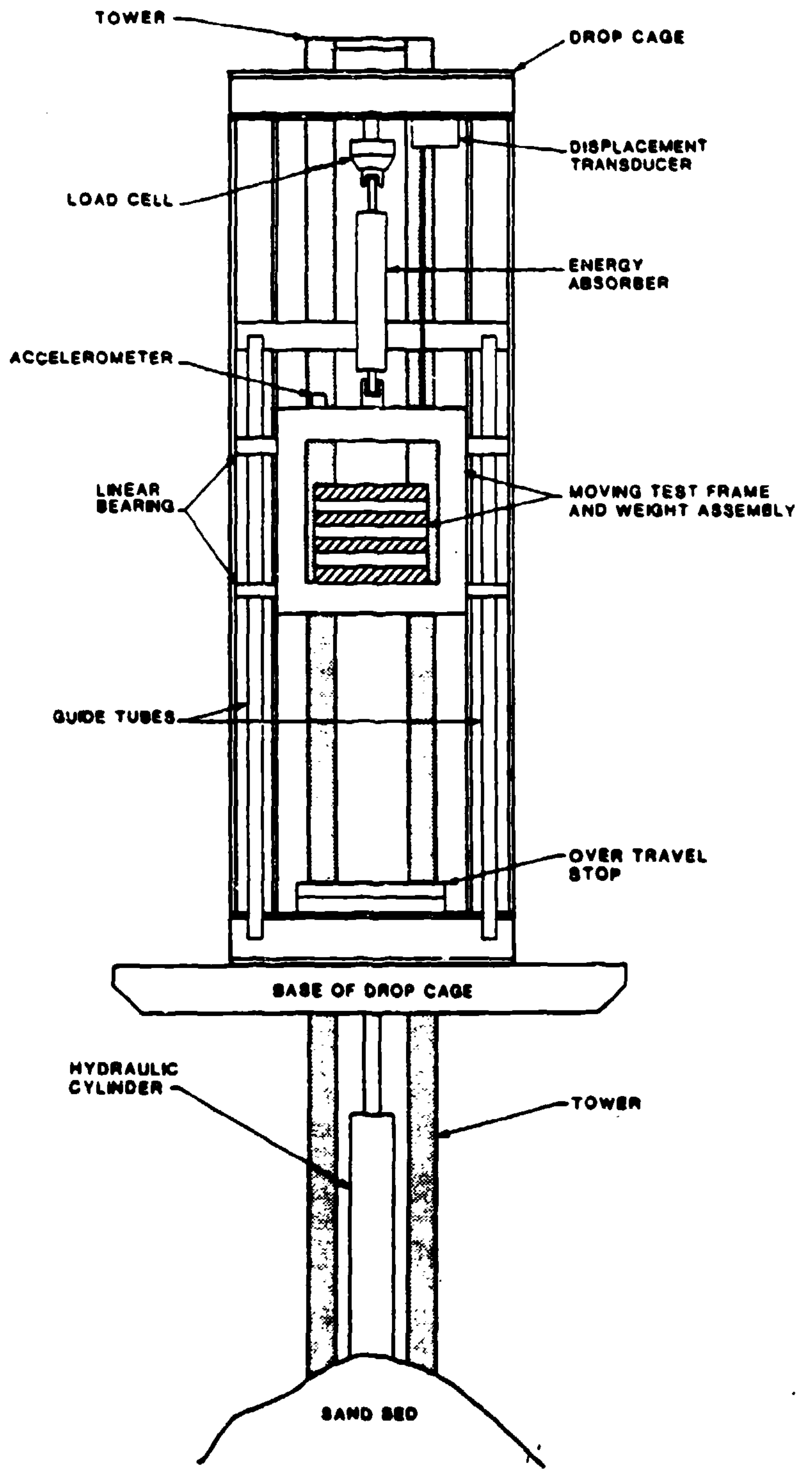


FIGURE 6. ENERGY ABSORBER DYNAMIC TEST APPARATUS.

7.0 TROOP SEAT ENERGY ABSORBER TEST RESULTS

7.1 REQUIREMENTS

Energy absorber load-deflection requirements per Sikorsky Aircraft were as follows:

- Desired Stroking Load: 1300 ± 150 lb
- Stroking Distance: 14.0 ± 0.25 in.

The stroke allowed to reach the desired load was not specified and was assumed to be 0.75 in. based on the results of typical dynamic tests. The desired load-deflection characteristics are superimposed on each plot as shown in Figure 7.

7.2 TROOP SEAT ENERGY ABSORBER STATIC TEST RESULTS

7.2.1 New Energy Absorbers

An example of a typical static test result for a new troop seat energy absorber is shown in Figure 8. The load peaked out at approximately 1170 lb and then dropped to a relatively steady load around 1070 lb, well below the desired minimum of 1150 lb. This response was similar for all four of the new energy absorbers, which had an average stroking load between 1059 and 1078 lb. Plots for the other three energy absorbers can be found in Appendix B.

7.2.2 Fielded Energy Absorbers

Two fielded energy absorbers from the same troop seat failed. Figure 9a shows the load-versus-displacment plot for one which failed at 1174 lb. The other energy absorber that failed (plot not shown) broke at 1087 lb. The two energy absorbers broke at the same location where the wire is suspended, as shown in Figure 10.

Two of the energy absorbers stroked. Figure 9b shows a load-versus-displacement curve for one which stroked at an average load of 1024 lb. The other energy absorber (plot not shown) stroked at an average load of 1009 lb.

Plots not shown here can be found in Appendix B.

7.3 TROOP SEAT ENERGY ABSORBER DYNAMIC TEST RESULTS

After the static testing was completed it was learned that new aircraft have a load-distributing saddle installed at the wire suspension point as shown in Figure 11. This modification was made to preclude wire failures at this location. Since the observed static test failures were at the suspension point, it was decided to test half of the remaining energy absorbers with the saddle installed to determine if this solution would alleviate dynamic failures.

A typical dynamic test input pulse is shown in Figure 12. This pulse has a peak of 22.4 G with an onset rate of approximately 1080 G/sec and total velocity change of 16.5 ft/sec. All energy absorbers were stroked at an average velocity between 8.0 and 11.6 ft/sec.

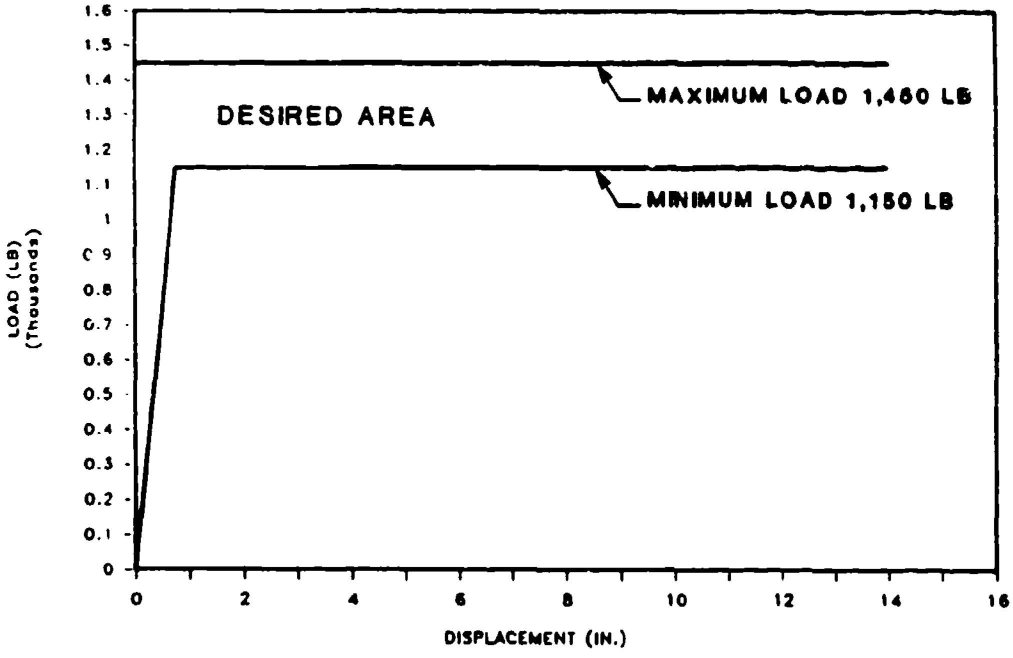


FIGURE 7. TROOP SEAT ENERGY ABSORBER LOAD-DISPLACEMENT REQUIREMENTS.

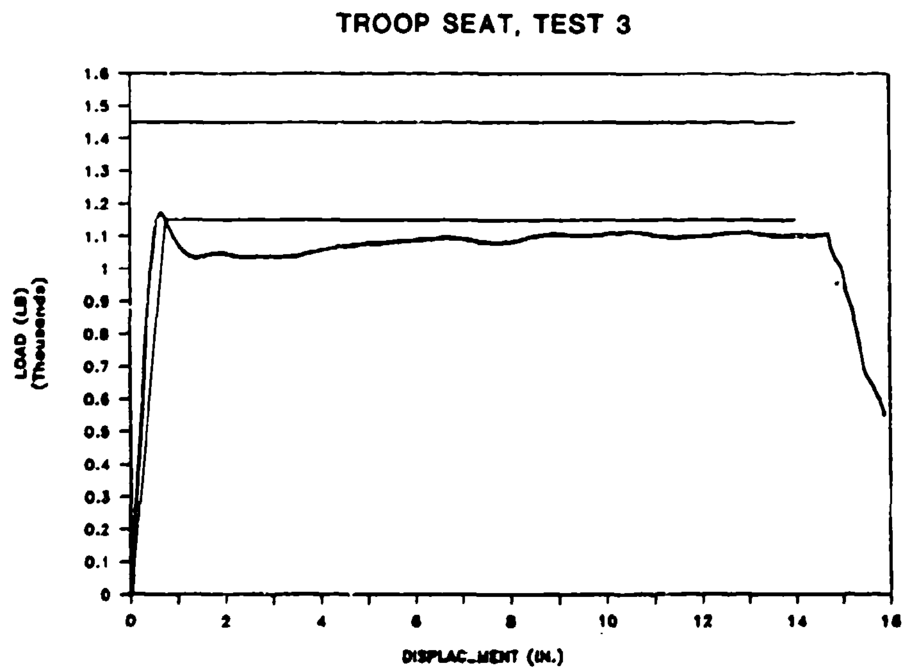
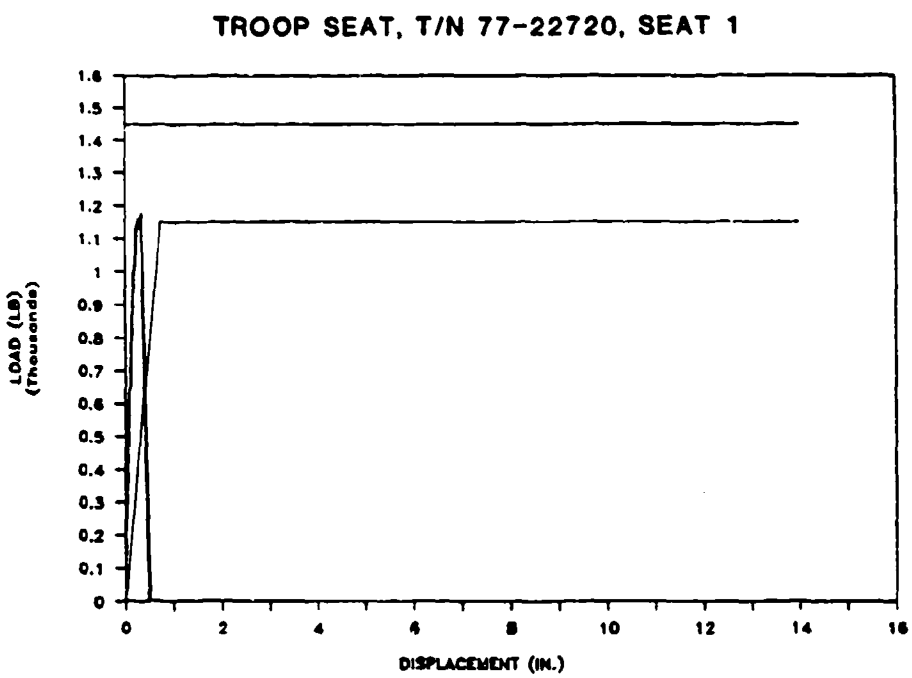


FIGURE 8. TYPICAL STATIC TEST RESULT - TROOP SEAT, NEW ENERGY ABSORBER.



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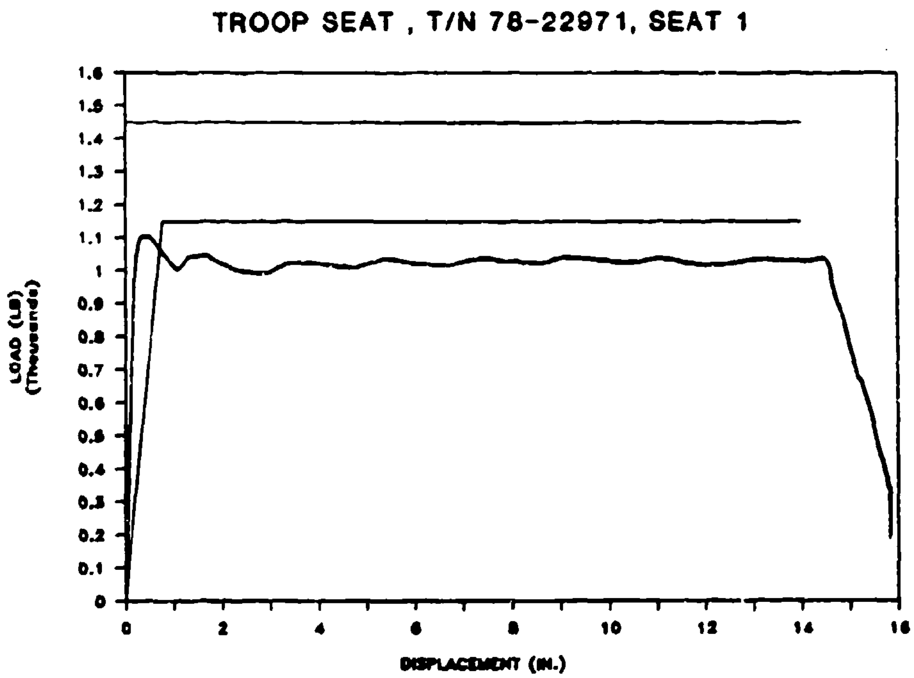


b.

FIGURE 9. TYPICAL STATIC TEST RESULTS - TROOP SEAT, FIELDED ENERGY ABSORBER.

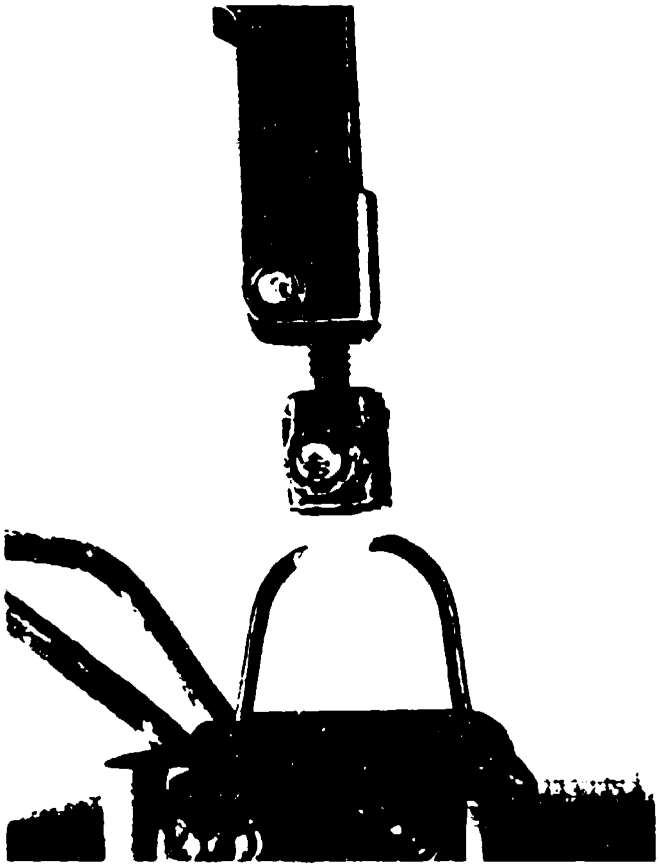


FIGURE 10. TYPICAL STATIC TEST FAILURE - TROOP SEAT, FIELDED ENERGY ABSORBER.

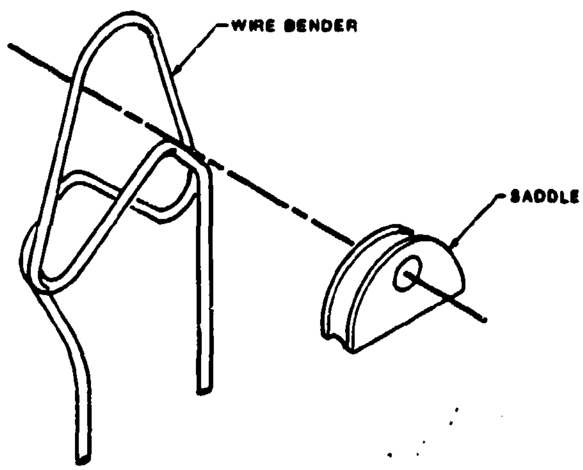


FIGURE 11. LOAD DISTRIBUTING SADDLE - TROOP SEAT DYNAMIC TESTING.

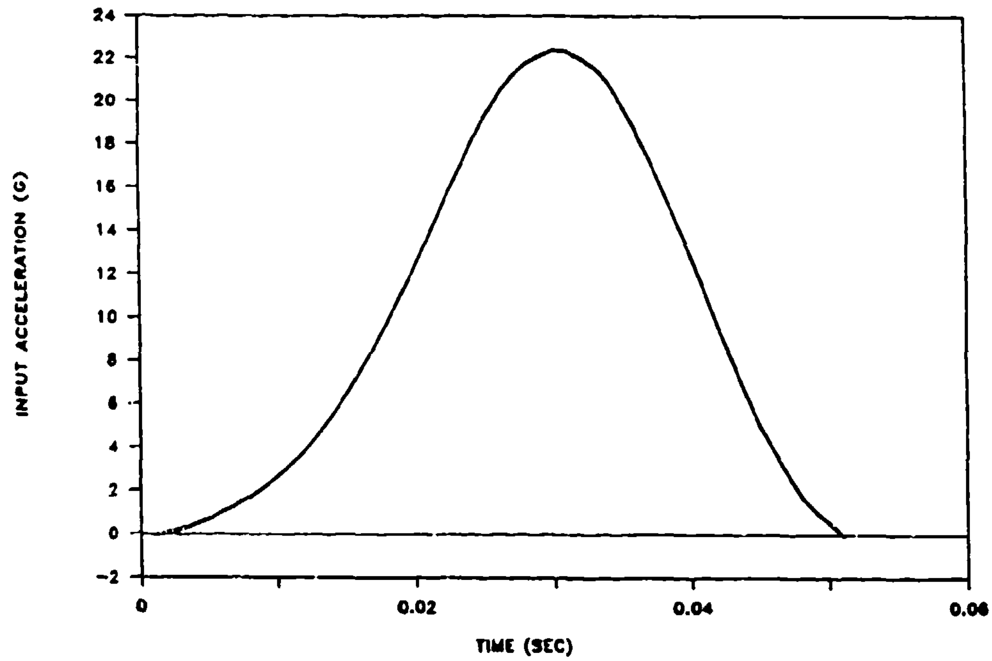


FIGURE 12. TYPICAL TROOP SEAT DYNAMIC TEST INPUT PULSE.

7.3.1 New Energy Absorbers

An example of a new troop seat energy absorber dynamic test result is shown in Figure 13. Plots for the other five energy absorbers can be found in Appendix B. The load-deflection characteristics were similar to those for the static tests.

All six of the new energy absorbers stroked at an average load beteen 987 and 1062 lb.

7.3.2 Fielded Energy Absorbers

Test result examples are presented in Figure 14. Twenty-two of 24 energy absorbers that stroked gave load-deflection characteristics similar to those shown in Figure 14a, with the average stroking load ranging between 942 and 1068 lb. Characteristics of the other two energy absorbers were relatively high and low. The plot for the highest energy absorber, which had an average load of 1302 lb, is shown in Figure 14b. This is the only energy absorber that stroked within the specified load limits. This energy absorber stopped short due to insufficient input energy from the dynamic test apparatus. Note that the load was continually increasing and may have exceeded the load-limit had stroke continued. Figure 14c shows the plot for the lowest energy absorber, which had an average stroking load of 757 lb.

The remaining 20 energy absorbers failed with similar load-deflection characteristics as those shown in Figure 14d. Plots of the remaining energy absorbers can be found in Appendix B.

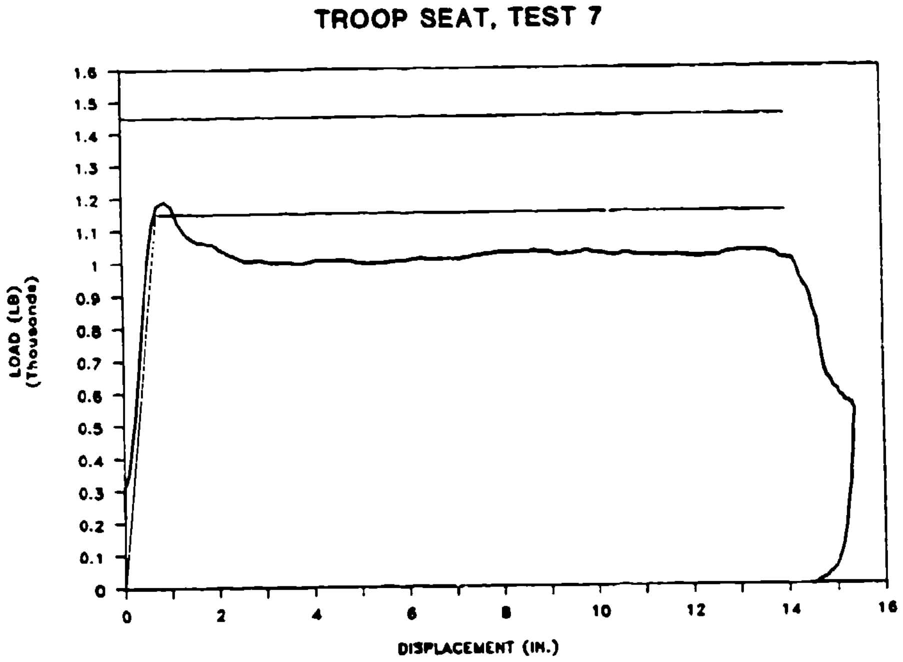


FIGURE 13. TYPICAL DYNAMIC TEST RESULT - TROOP SEAT, NEW ENERGY ABSORBER.

Figure 15 shows an example of a wire fracture. Breakage points of all failures were in the area where the wire wraps around the rollers. The wires experienced necking-down in the area of the fracture.

7.4 TROOP SEAT ENERGY ABSORBER TEST RESULT SUMMARY

Troop seat energy absorber test results are summarized in Table 5. This table identifies the energy absorbers by seat number and aircraft tail number. The seat numbers were selected at random and do not relate to any specific location in the aircraft. Also shown is the total energy absorbed, which is the integral of force versus displacement. For the energy calculations, the load was assumed constant during the remaining stroke if the stroke stopped short of 14 in. for any reason other than failure.

Plots of all test results are included in Appendix B. Table 6 shows the calculated average stroking loads and the calculated standard deviation of the energy absorbers that did not fail.

Table 7 shows the failure rate summary, including the energy absorber that broke after stroking (T/N 77-22720, Seat 9a). Note that aircraft 77-22720 had approximately twice the failures and flight hours of aircraft 78-22971 but was just 5 months older. This suggests that the failures are related to flight time rather than age.

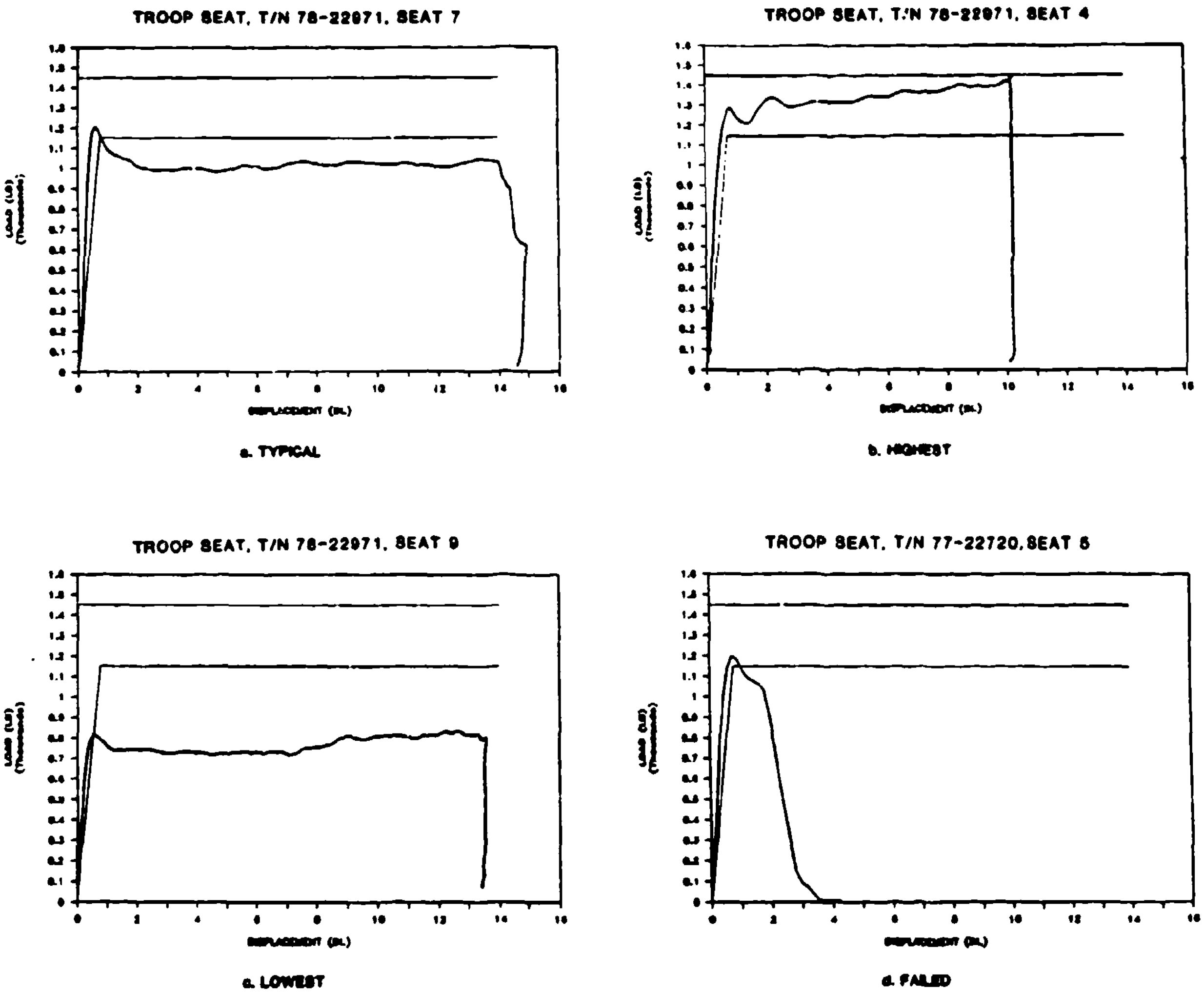


FIGURE 14. TYPICAL DYNAMIC TEST RESULTS - TROOP SEAT, FIELDED ENERGY ABSORBERS.

All dynamic failures occurred where the wire wraps around the rollers, indicating that the load distributing saddles were not a factor (11 broke with the saddle, 12 without). None of the new energy absorbers failed. The average load of new energy absorbers were only slightly higher (2.6 percent) than the fielded energy absorbers that did not fail. The energy absorbers consistently stroked approximately 280 lb under the desired nominal load of 1300 lb, with the exception of aircraft 78-22971 (seats 4a and 9b), which stroked at an average load of 1302 and 757 lb, respectively.

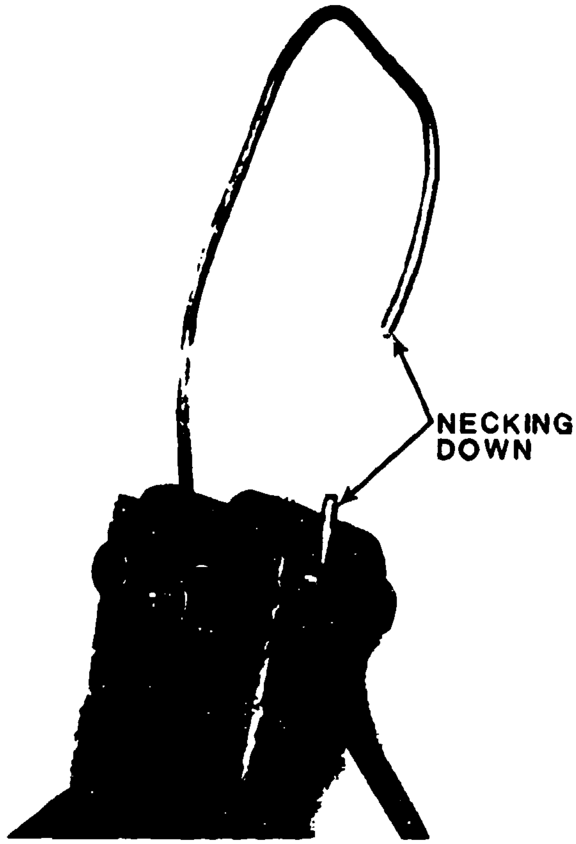


FIGURE 15. TYPICAL WIRE FRACTURE DURING DYNAMIC TESTING - TROOP SEAT, FIELDED ENERGY ABSORBER.

7.5 TROOP SEAT POSTTEST INSPECTION

Two phenomena were noted upon posttest inspection of wires. The dynamically failed wires showed necking-down (severe deformation) of the wire diameter at the fracture point (see Figure 15). It was originally believed that the necking-down was only a result of the ductility in the wire and occurred as the wire was loaded to failure. However, inspection of wires that did not fail revealed some of these also had areas of necking-down as shown in Figure 16. Therefore, it appears that the initiation of the necking-down phenomenon occurred previous to, rather than during, the dynamic testing. The location of the neck-down area was measured and found to be approximately at the midpoint of the preformed minimum bend radius (0.19 in.) as shown in Figure 17. All of the dynamically failed wires broke in this area. The second phenomenon observed was localized flat spotting of wires due to contact with the rollers. This wear resulted at points of suspension due

TABLE 5. TROOP SEAT ENERGY ABSORBER TEST RESULTS SUMMARY

Energy Absorber Seat No.	Aircraft T/N	Test Type Static	Test Type Dynamic	Saddle Used Yes	Saddle Used No	Energy[1] Absorbed (in.-lb)	Average[3] Stroking Load (lb)	Peak Load (lb)	Meets Manufacturer Requirements Yes	Meets Manufacturer Requirements No	Appendix B Figure No.
1	77-22720	X			X	243	-	1,087		X	B-1a
1		X			X	390	-	1,174		X	B-1b
2			X	X		3,082	-	1,295		X	B-2a
2			X		X	1,631	-	1,097		X	B-2b
3			X	X		13,180	942	1,097		X	B-3a
3			X		X	13,710	977	1,136		X	B-3b
4			X	X		13,339	953	1,125		X	B-4a
4			X		X	13,164	933	1,110		X	B-4b
5			X	X		1,088	-	1,220		X	B-5a
5			X		X	2,380	-	1,201		X	B-5b
6			X	X		2,385	-	1,237		X	B-6a
6			X	X		713	-	710		X	B-6b
7			X		X	14,948	1,066	1,222		X	B-7a
7			X	X		13,671	985	1,094		X	B-7b
8			X		X	1,159	-	1,207		X	B-8a
8			X	X		2,263	-	1,216		X	B-8b
9			X	X		14,598	1,038[2]	1,251		X	B-9a
9			X		X	2,127	-	1,229		X	B-9b
10			X	X		14,516	1,028	1,216		X	B-10a
10			X		X	1,207	-	1,148		X	B-10b
11			X	X		1,456	-	1,242		X	B-11a
11			X		X	1,456	-	1,210		X	B-11b
12			X	X		14,344	1,017	1,201		X	B-12a
12			X		X	858	-	1,145		X	B-12b
1	78-22971	X			X	14,133	1,009	1,063		X	B-13a
1		X			X	14,317	1,024	1,106		X	B-13b
2			X		X	14,330	1,021	1,220		X	B-14a
2			X	X		1,209	-	1,233		X	B-14b
3			X		X	14,557	1,041	1,191		X	B-15a
3			X	X		14,577	1,042	1,233		X	B-15b
4			X		X	18,718	1,302	1,445	X[4]		B-16a
4			X	X		14,959	1,068	1,244		X	B-16b
5			X		X	14,923	1,065	1,212		X	B-17a
5			X	X		13,977	998	1,144		X	B-17b

(1) For the energy calculations, the load was assumed constant during the remaining stroke if the stroke stopped short of 14 in. for any reason other than failure.
(2) Energy absorber broke after stroking.
(3) Average stroking load only calculated for those energy absorbers which did not fail.
(4) Stroked short of required distance. If stroke would have continued, force-deflection requirements may have been violated.

TABLE 5 (CONTD). TROOP SEAT ENERGY ABSORBER TEST RESULTS SUMMARY

Energy Absorber Seat No.	Aircraft T/N	Test Type Static	Test Type Dynamic	Saddle Used Yes	Saddle Used No	Energy[1] Absorbed (in.-lb)	Average[3] Stroking Load (lb)	Peak Load (lb)	Meets Manufacturer Requirements Yes	Meets Manufacturer Requirements No	Appendix B Figure No.
6	78-22971		X		X	14,526	1,037	1,181		X	B-18a
6	(contd)		X		X	13,950	998	1,116		X	B-18b
7			X	X		14,144	1,009	1,230		X	B-19a
7			X		X	1,203	-	1,170		X	B-19b
8			X	X		2,127	-	1,222		X	B-20a
8			X		X	14,298	1,022	1,179		X	B-20b
9			X	X		10,618	757	833		X	B-21a
9			X		X	14,659	1,045	1,210		X	B-21b
10			X	X		696	-	681		X	B-22a
10			X		X	2,224	-	1,224		X	B-22b
11			X	X		14,323	1,020	1,216		X	B-23a
11			X		X	13,977	999	1,157		X	B-23b
12			X	X		1,080	-	1,175		X	B-24a
12			X		X	2,992	-	1,136		X	B-24b
1	N/A New	X			X	14,821	1,059	1,130		X	B-25a
2		X			X	14,820	1,059	1,154		X	B-25b
3		X			X	14,965	1,068	1,186		X	B-26a
4		X			X	15,101	1,078	1,132		X	B-26b
5			X		X	14,917	1,062	1,225		X	B-27a
6			X		X	14,985	1,070	1,222		X	B-27b
7			X	X		14,143	1,012	1,192		X	B-28a
8			X		X	14,122	1,012	1,166		X	B-28b
9			X	X		13,891	992	1,161		X	B-29a
10			X		X	13,744	987	1,146		X	B-29b

(1) For the energy calculations, the load was assumed constant during the remaining stroke if the stroke stopped short of 14 in. for any reason other than failure.

(2) Energy absorber broke after stroking.

(3) Average stroking load only calculated for those energy absorbers which did not fail.

(4) Stroked short of required distance. If stroke would have continued, force-deflection requirements may have been violated.

TABLE 6. AVERAGE STROKING LOADS OF TROOP SEAT ENERGY ABSORBERS

Aircraft T/N	Average Load (lb)	Standard Deviation (lb)
77-22720	991	47
78-22971	1027	99
All Fielded Energy Absorbers	1014	85
All New Energy Absorbers	1040	35

TABLE 7. TROOP SEAT ENERGY ABSORBER FAILURE RATE SUMMARY

Aircraft T/N	Aircraft Delivery Date	Operational Hours	Number of Failed Energy Absorbers	Failure (%)
77-22720	5/79	2281	16 of 24	67
78-22971	10/79	1200	7 of 24	29

to the normal movement of seats (occupied and unoccupied) in the aircraft while subjected to vibratory flight loads. This localized wear appeared to be more severe in the -971 wires. Measurements made in the areas of localized wear revealed diameter reductions as much as 0.0025 in. when compared to unworn areas. None of the wires failed in the worn area.

A loss of cadmium plating (used as a dry lubricant) on almost all of the fielded wires was also observed along with varying degrees of light corrosion and debris in the wire-roller area. The roller mounting bolts also showed evidence of corrosion which served to increase friction and make the rollers more resistant to turning.

Metallurgical inspection of the failed energy absorbers determined that all wire fractures were due to overstress. Table 8 compares the measured average peak load of the failed and successful energy absorbers for the three sources: T/N 720, T/N 971 and new (depot).

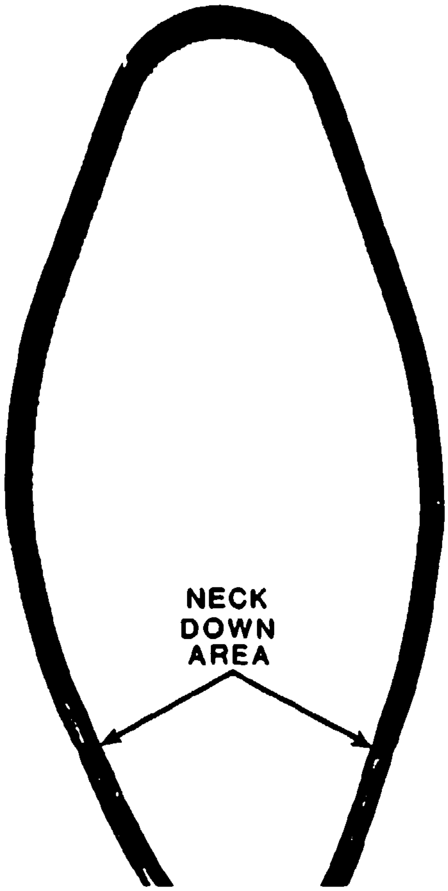


FIGURE 16. TROOP SEAT WIRE NECKING-DOWN.

Since the peak load of the failed attenuators is approximately the same as the successful attenuators, it is concluded that the overstress was not caused by overload. The calculated direct tensile failure load of the attenuator is over 4000 lb, well above the loads experienced during these tests. This indicates that the overstress must be caused by some other mechanism such as a reduction in cross-sectional area, a reduction in the strength of the material, high localized bending stresses, or a combination of these factors.

The exact mechanism of wire failures is still not understood and is being investigated by U.S. Army personnel at the time of this report. Additional testing to isolate the failure mechanism may be required.

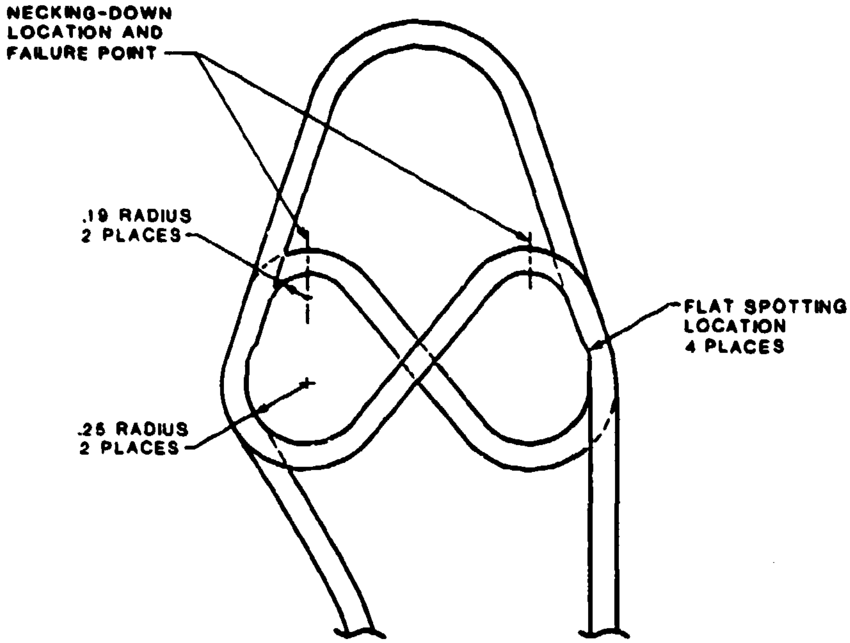


FIGURE 17. PREFORMED WIRE LOCATION OF DYNAMIC FAILURES AND LOCALIZED WEAR.

TABLE 8. PEAK STROKING/FAILURE LOAD COMPARISON OF TROOP SEAT ENERGY ABSORBERS

E/A Source	Average Peak Load Successful Attenuators (lb)	Average Peak Load Failed Attenuators (lb)
T/M 77-22720	1161	1161
T/M 78-22971	1175	1120
New (Depot)	1171	N/A

8.0 ARA CREW SEAT ENERGY ABSORBER TEST RESULTS

8.1 REQUIREMENTS

The load-deflection requirements for the energy absorbers as interpreted from ARA Drawing No. D3874 are presented in Figure 18. The desired load-deflection characteristics are superimposed on each plot as shown in Figure 19. The energy absorber base part number of "D3874" will not be used in the remainder of this report for abbreviation. All of the -3 energy absorbers were tested in compression.

8.2 ARA CREW SEAT ENERGY ABSORBER STATIC TEST RESULTS

8.2.1 New Energy Absorbers

Plots of the static test results for the new ARA energy absorbers are shown in Figure 20. The -1 and -3 energy absorbers did not fall within the specified limits for the entire stroke. The -3 energy absorbers were both high, and one -1 was high and the other low at the end of the stroke. Both -2 energy absorbers met the desired load-deflection characteristics.

8.2.2 Fielded Energy Absorbers

Plots of the static test results for the fielded ARA energy absorbers are shown in Figure 21. The load-deflection response of the fielded units was similar to that of the new units in that both -3 energy absorbers were high, and one -1 was high and the other low at the end of stroke. Both -2 energy absorbers met the specified load-deflection requirements.

8.3 ARA ENERGY ABSORBER DYNAMIC TEST RESULTS

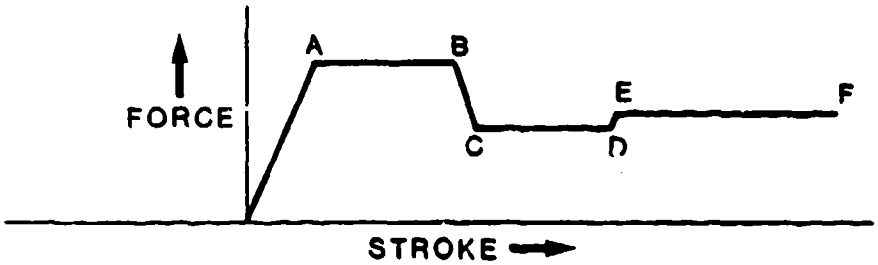
The -1 energy absorbers were stroked at an average velocity of between 6.3 and 7.1 ft/sec, the -2 between 6.8 and 10.1 ft/sec, and the -3 between 3.8 and 4.6 ft/sec.

8.3.1 New Energy Absorbers

Examples of dynamic test results for the new ARA energy absorbers are shown in Figure 22. The -1 energy absorbers were typically low at the start of the stroke and high at the end of the stroke. The -2 energy absorbers were also typically low at the start of the stroke but usually within the corridor, and then climbed out of the corridor toward the end of the stroke. The -3 energy absorbers were all well above the desired stroking range. Plots for the remaining new energy absorbers can be found in Appendix C.

8.3.2 Fielded Energy Absorbers

Examples of dynamic test results for the fielded ARA energy absorbers are shown in Figure 23. In general the dynamic response of the fielded energy absorbers was similar to that of the new energy absorbers. Selected worst-case examples are shown in Figure 24. Plots for the remaining fielded energy absorbers can be found in Appendix C.



		LOWER LIMIT		UPPER LIMIT	
P/N	POINT	STROKE	FORCE	STROKE	FORCE
-1	A	0.45	2,400	0.05	3,000
	B	1.40	2,400	1.80	3,000
	C	2.07	1,350	2.53	1,650
	D	3.30	1,350	2.70	1,650
	E	3.35	1,440	2.75	1,760
	F	5.13	1,440	5.70	1,760
-2	A	0.38	1,500	0.00	2,100
	B	1.80	1,500	2.20	2,100
	C	2.47	250	3.03	550
	D	6.82	250	5.58	550
	E	6.85	350	5.61	650
	F	10.98	350	12.20	650
-3	A	0.40	1,100	0.00	1,400
	B	2.81	1,100	2.90	1,400

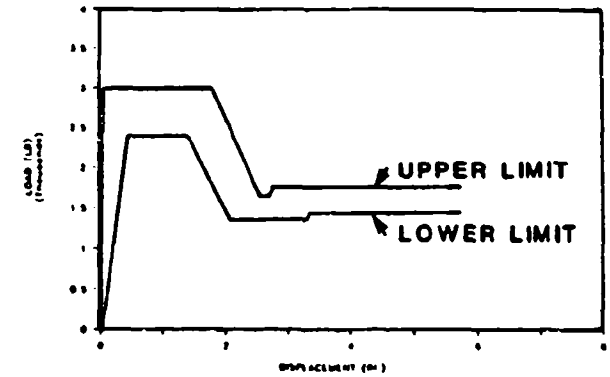
NOTES: 1. FORCE LEVELS 'C' TO 'D' AND 'E' TO 'F' ARE INTERCHANGEABLE

2. FORCE LEVELS MAY EXCEED LIMITS SHOWN FOR 0.50 IN. STROKE MAXIMUM IF THE ENERGY IS LESS THAN 2% OF THE TOTAL NOMINAL DESIGN ENERGY

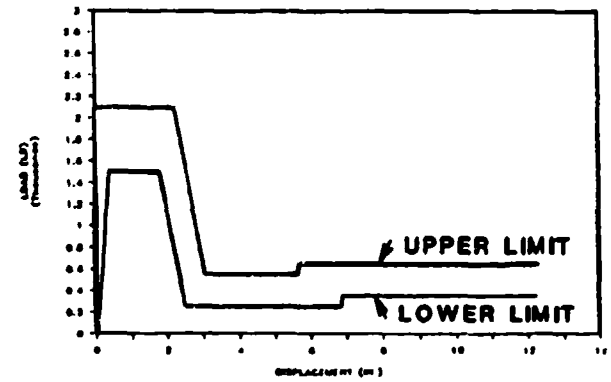
3. -1 AND -2 ENERGY ABSORBERS TESTED IN TENSION, -3 ENERGY ABSORBERS TESTED IN COMPRESSION

FIGURE 18. ARA CREW SEAT ENERGY ABSORBER LOAD-DEFLECTION REQUIREMENTS.

P/N D3874-1



P/N D3874-2



P/N D3874-3

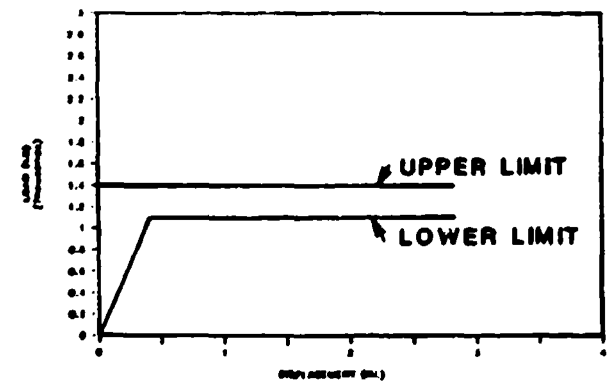


FIGURE 19. ARA ENERGY ABSORBER LOAD-DISPLACEMENT CORRIDORS.

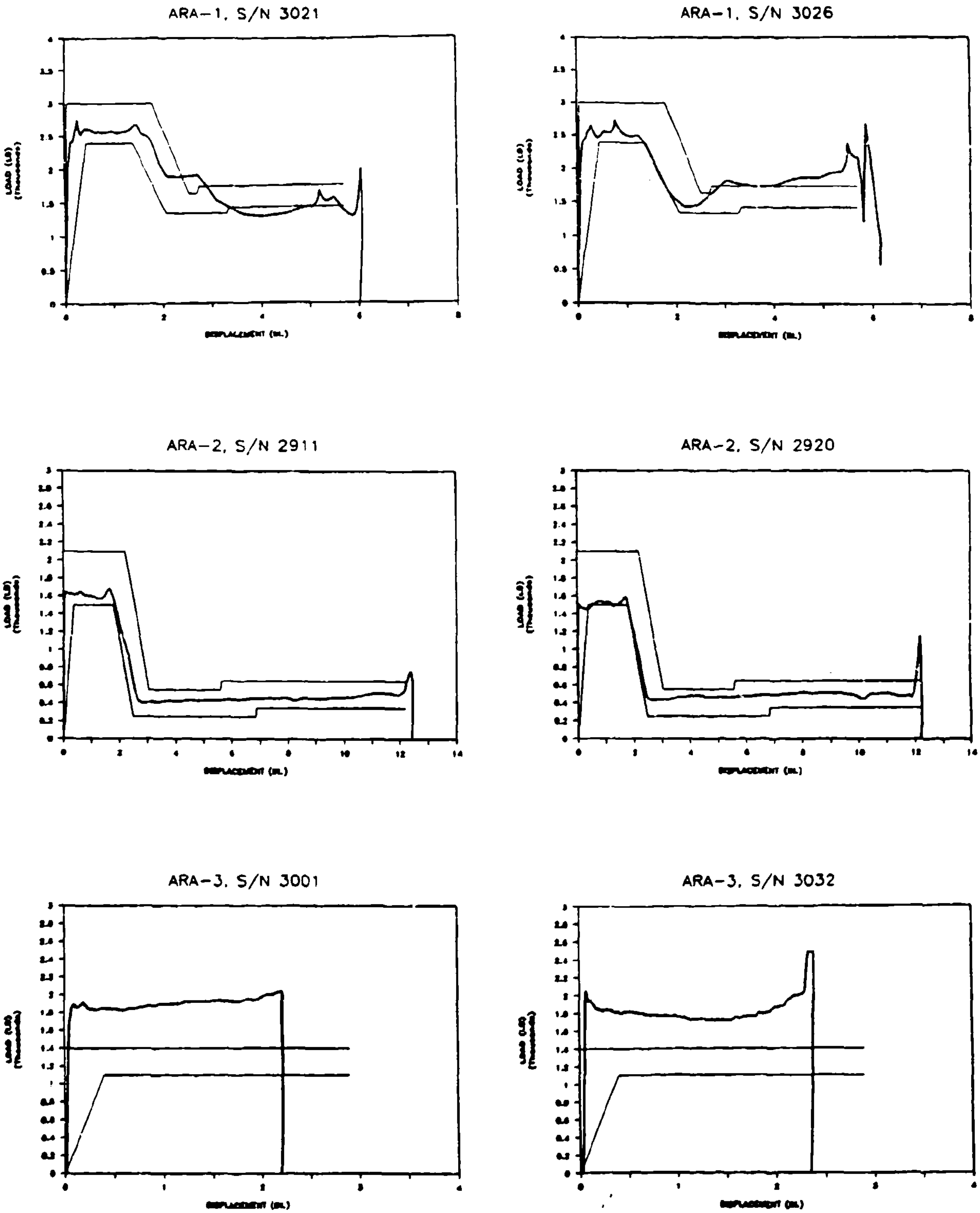


FIGURE 20. STATIC TEST RESULTS - ARA CREW SEAT, NEW ENERGY ABSORBERS.

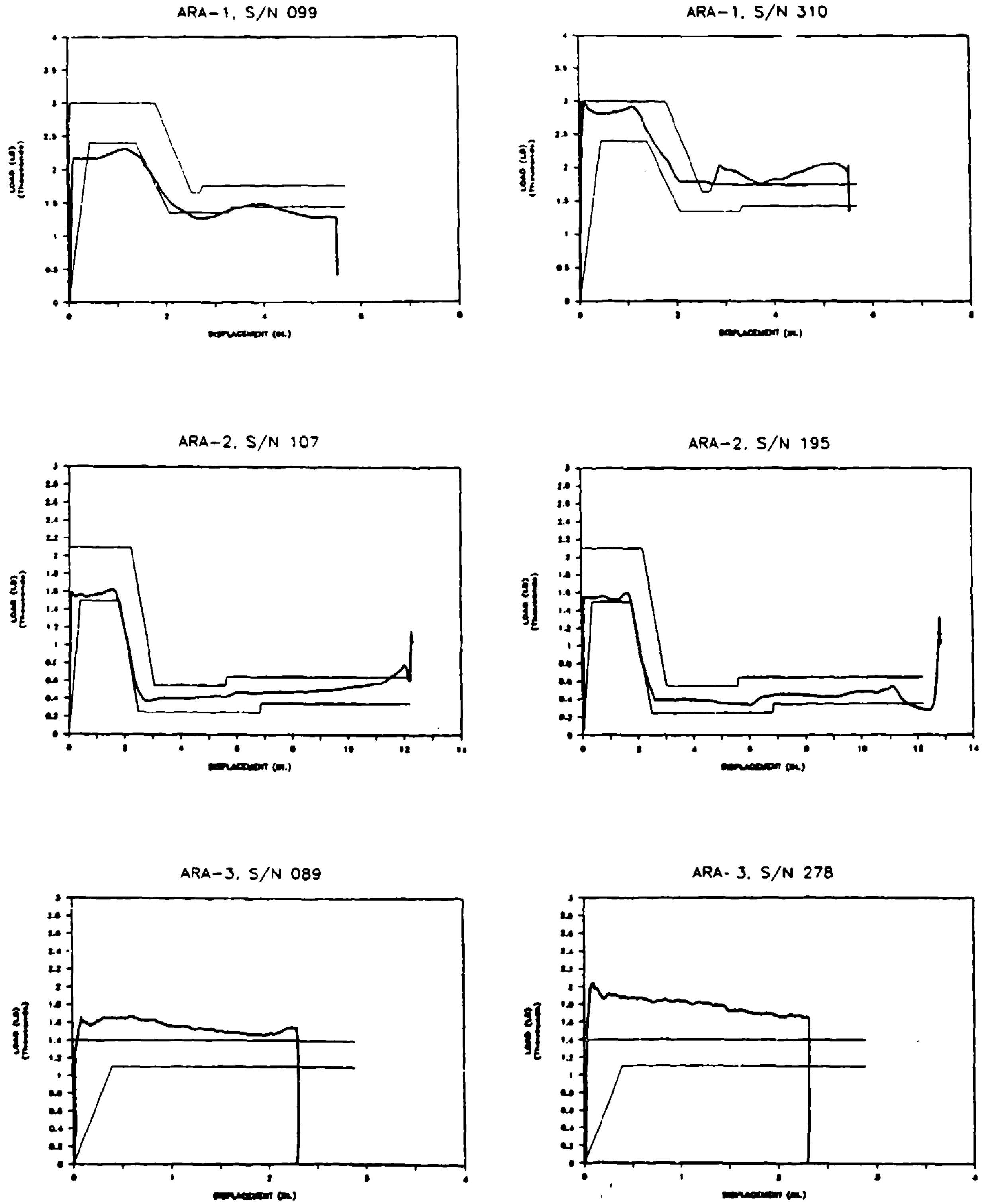


FIGURE 21. STATIC TEST RESULTS - ARA CREW SEAT, FIELDED ENERGY ABSORBERS.

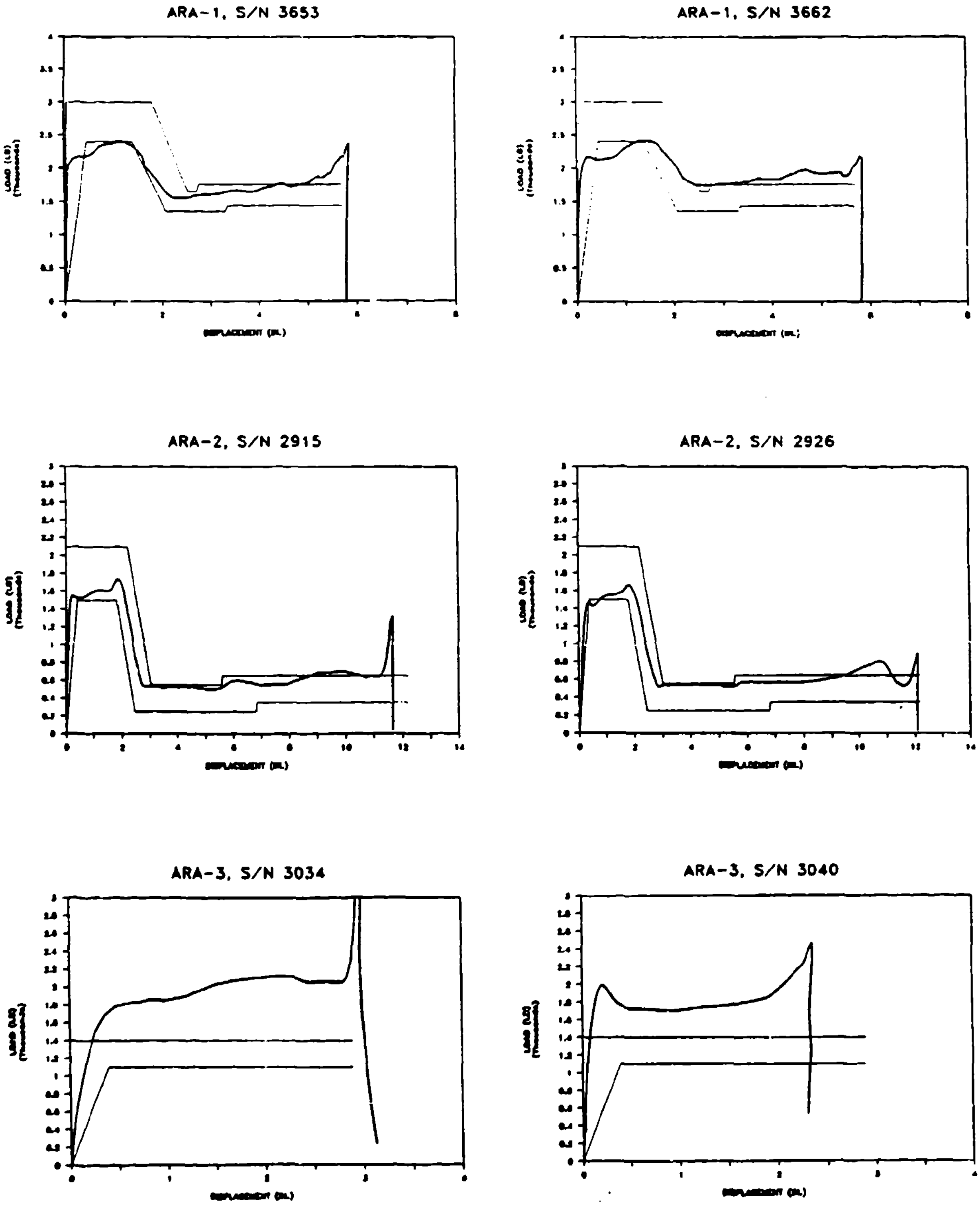


FIGURE 22. TYPICAL DYNAMIC TEST RESULTS - ARA CREW SEAT, NEW ENERGY ABSORBERS.

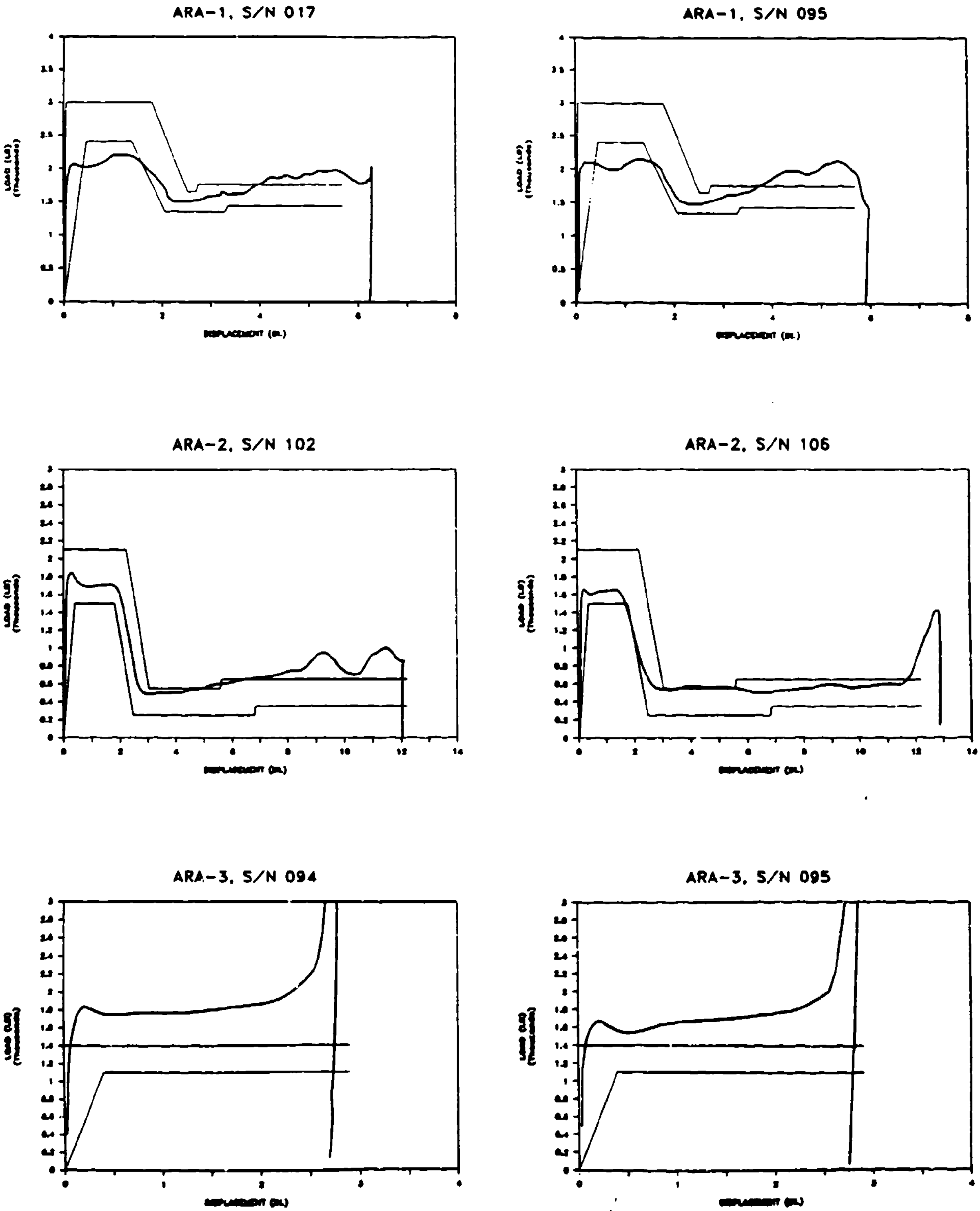


FIGURE 23. TYPICAL DYNAMIC TEST RESULTS - ARA CREW SEAT, FIELDED ENERGY ABSORBERS.

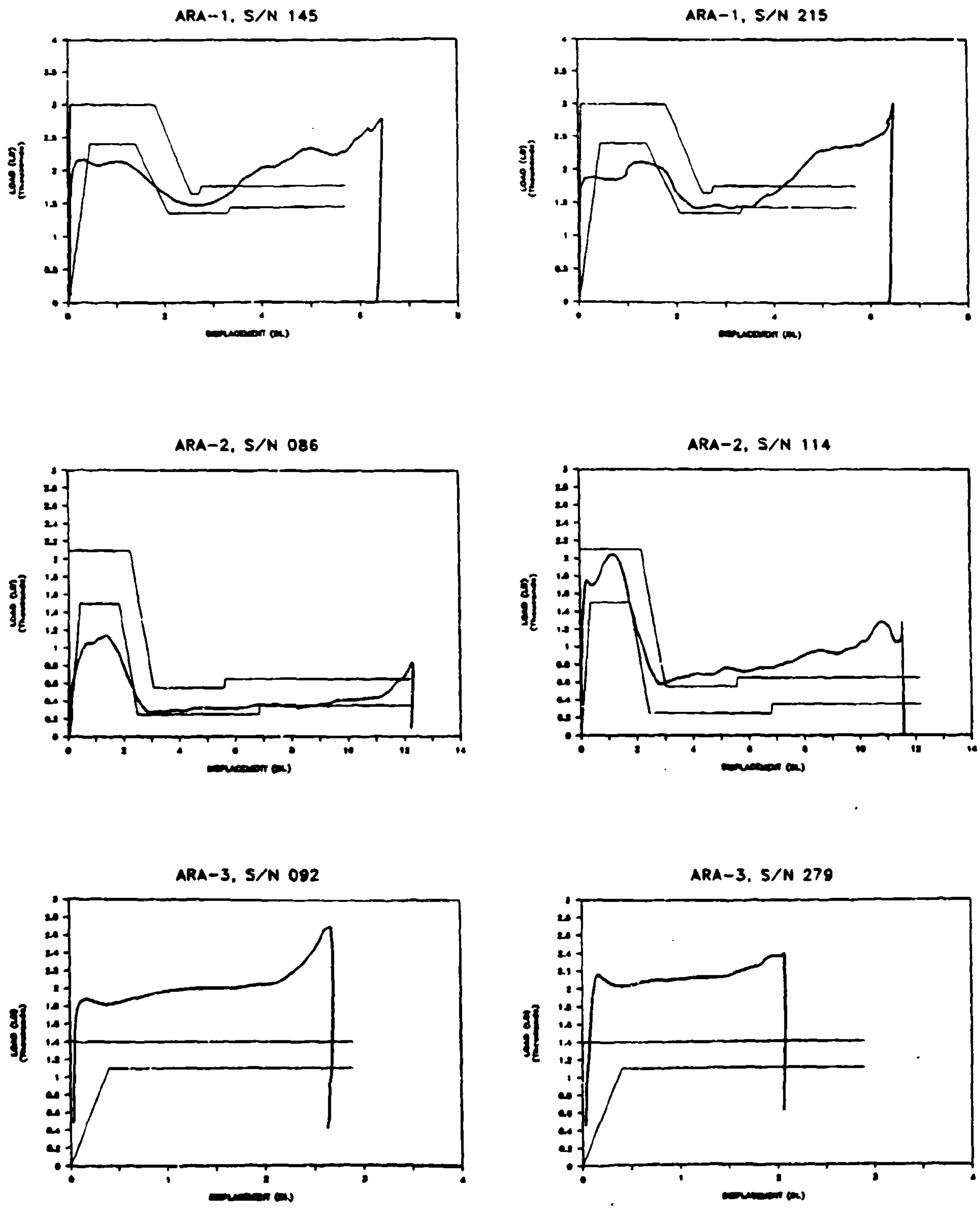


FIGURE 24. WORST-CASE DYNAMIC TEST RESULTS - ARA CREW SEAT, FIELDED ENERGY ABSORBERS.

8.4 ARA CREW SEAT ENERGY ABSORBER TEST RESULT SUMMARY

ARA crew seat energy absorber test results are summarized in Table 9.

TABLE 9. ARA CREW SEAT ENERGY ABSORBER TEST RESULTS SUMMARY

Energy Absorber P/N	Energy Absorber S/N	Aircraft T/N	Test Type		Energy[1] Absorbed (in.-lb)	Average Stroking Load (lb)	Meets Manufacturer Requirements				Appendix C Figure No.
							Energy[1]		Load-Deflection		
			Static	Dynamic			Yes	No	Yes	No	
-1	95	81-23597		X	10,684	1,817	X			X	C-1b
-1	103			X	10,303	1,814	X			X	C-1a
-2	91			X	9,710	795	X			X[2]	C-1d
-2	106			X	9,158	751	X			X[2]	C-1c
-3	101			X	5,290	1,824		X		X	C-1f
-3	106			X	4,974	1,906		X		X	C-1e
-1	99		X		9,154	1,623		X		X	C-2b
-1	114			X	10,111	1,774	X			X	C-2a
-2	86			X	5,841	480		X		X	C-2c
-2	97			X	9,592	787	X			X	C-2d
-3	95			X	5,468	1,885		X		X	C-2f
-3	114			X	5,350	1,639		X		X	C-2e
-1	101	81-23598		X	10,361	1,821	X			X	C-3b
-1	140			X	10,111	1,771	X			X	C-3a
-2	109			X	11,512	944		X		X	C-3d
-2	114			X	12,225	1,002		X		X	C-3c
-3	83			X	5,298	1,827		X		X	C-3f
-3	94			X	5,405	1,931		X		X	C-3e
-1	17			X	10,624	1,857	X			X	C-4b
-1	120			X	10,457	1,838	X			X	C-4a
-2	88			X	9,299	793	X			X	C-4c
-2	107		X		8,183	669	X		X		C-4d
-3	1			X	5,306	1,881		X		X	C-4f
-3	92			X	5,393	2,005		X		X	C-4e
-1	118	81-23501		X	9,750	1,708	X			X	C-5b
-1	137			X	9,910	1,742	X			X	C-5a
-2	72			X	9,211	754	X			X	C-5d
-2	102			X	10,633	878	X			X	C-5c
-3	79			X	4,870	1,703		X		X	C-5e
-3	103			X	5,016	1,730		X		X	C-5f

(1) Calculated energy ranges: (-1) 9,191 to 12,580 in.-lb
(-2) 5,970 to 11,424 in.-lb
(-3) 2,970 to 3,654 in.-lb

For the energy calculations, the load was assumed constant during the remaining stroke if the stroke stopped short of 14 in. for any reason other than failure.

(2) Force-deflection characteristics very close to desired response.

(3) Stroke short of required distance. If stroke would have continued, force-deflection requirements may have been violated.

TABLE 9 (CONTD). ARA CREW SEAT ENERGY ABSORBER TEST RESULTS SUMMARY

Energy Absorber P/N	Energy Absorber S/N	Aircraft T/N	Test Type		Energy[1] Absorbed (in.-lb)	Average Stroking Load (lb)	Meets Manufacturer Requirements				Appendix C Figure No.
							Energy[1]		Load-Deflection		
			Static	Dynamic			Yes	No	Yes	No	
-1	142			X	10,047	1,763	X			X	C-6a
-1	145			X	11,250	1,967	X			X	C-6b
-2	101			X	9,005	738	X			X[2]	C-6d
-2	112			X	9,547	781	X			X[2]	C-6c
-3	89		X		4,495	1,534		X		X	C-6f
-3	98			X	5,117	1,808		X		X	C-6e
-1	208	81-23619		X	10,148	1,918	X			X	C-7a
-1	215			X	10,668	1,868	X			X	C-7b
-2	158			X	7,747	636	X		X		C-7d
-2	163			X	9,034	740	X			X	C-7c
-3	172			X	5,556	1,700		X		X	C-7e
-3	174			X	5,853	2,018		X		X	C-7f
-1	209			X	9,361	1,651	X			X	C-8b
-1	216			X	10,609	1,861	X			X	C-8a
-2	188			X	8,314	682	X			X	C-8d
-2	195		X		7,390	606	X		X		C-8c
-3	168			X	5,509	1,967		X		X	C-8e
-3	179			X	5,638	1,889		X		X	C-8f
-1	310	82-23678	X		12,352	2,167	X			X	C-9a
-1	311			X	11,439	2,012	X		X[3]		C-9b
-2	259			X	9,758	800	X			X	C-9c
-2	262			X	10,325	846	X			X	C-9d
-3	278		X		5,056	1,771		X		X	C-9e
-3	279			X	6,494	2,083		X		X	C-9f
-1	316			X	11,747	2,061	X			X	C-10a
-1	321			X	11,008	1,931	X		X[3]		C-10b
-2	265			X	9,939	815	X			X	C-10c
-2	268			X	11,243	921	X			X	C-10d
-3	280			X	5,298	1,999		X		X	C-10e
-3	281			X	4,977	1,765		X		X	C-10f
-1	3013	N/A New		X	11,179	1,954	X			X	C-11a
-1	3021		X		10,683	1,871	X			X	C-11b
-1	3023			X	12,195	2,139	X			X	C-12a

(1) Calculated energy ranges: (-1) 9,191 to 12,580 in.-lb
(-2) 5,970 to 11,424 in.-lb
(-3) 2,970 to 3,654 in.-lb

For the energy calculations, the load was assumed constant during the remaining stroke if the stroke stopped short of 14 in. for any reason other than failure.

(2) Force-deflection characteristics very close to desired response.

(3) Stroke short of required distance. If stroke would have continued, force-deflection requirements may have been violated.

TABLE 9 (CONTD). ARA CREW SEAT ENERGY ABSORBER TEST RESULTS SUMMARY

Energy Absorber P/N	Energy Absorber S/N	Aircraft T/N	Test Type Static	Test Type Dynamic	Energy[(1)] Absorbed (in.-lb)	Average Stroking Load (lb)	Meets Manufacturer Requirements: Energy[(1)] Yes	Energy[(1)] No	Load-Deflection Yes	Load-Deflection No	Appendix C Figure No.
-1	3026		X		11,276	1,975	X			X	C-12b
-1	3034			X	9,922	1,741	X			X	C-13a
-1	3039			X	10,772	1,890	X			X	C-13b
-1	3653			X	10,703	1,878	X			X	C-14a
-1	3662			X	11,360	1,993	X			X	C-14b
-2	2907			X	9,928	817	X			X(2)	C-11c
-2	2911		X		8,114	665	X		X		C-11d
-2	2915			X	9,236	793	X			X	C-12c
-2	2920		X		8,168	670	X		X		C-12d
-2	2926			X	9,321	770	X			X	C-13c
-2	2928			X	9,370	797	X			X	C-13d
-2	3555			X	10,799	884	X			X	C-14c
-2	3558			X	9,604	787	X			X	C-14d
-3	2996			X	6,208	2,133		X		X	C-11e
-3	3001		X		5,752	1,948		X		X	C-11f
-3	3003			X	6,180	1,914		X		X	C-12e
-3	3011			X	5,222	1,801		X		X	C-12f
-3	3017			X	5,062	1,858		X		X	C-13e
-3	3032		X		4,295	1,790		X		X	C-13f
-3	3034			X	5,535	1,909		X		X	C-14f
-3	3040			X	5,715	1,971		X		X	C-14e

(1) Calculated energy ranges: (-1) 9,191 to 12,580 in.-lb
(-2) 5,970 to 11,424 in.-lb
(-3) 2,970 to 3,654 in.-lb

For the energy calculations, the load was assumed constant during the remaining stroke if the stroke stopped short of 14 in. for any reason other than failure.

(2) Force-deflection characteristics very close to desired response.

(3) Stroke short of required distance. If stroke would have continued, force-deflection requirements may have been violated.

Table 10 shows the calculated average stroking loads and the calculated standard deviation for each attenuator test series. In general, neither the new or fielded energy absorbers met the manufacturer's specified load-deflection characteristics. Five of the 60 fielded energy absorbers and two of 24 new energy absorbers met the specified load-deflection characteristics. The -2 energy absorbers were, in general, closest to the desired response. The -3 energy absorbers were all significantly higher than the desired stroking load. The -1 and -2 energy absorbers were typically low at the start of the stroke and then high at the end of the stroke so that the calculated energy absorbed (average stroking load) was within the desired range. Discounting the -3 energy absorbers, 36 of 40 fielded energy absorbers and all of the new energy absorbers met the desired calculated energy range.

TABLE 10. ARA ENERGY ABSORBER AVERAGE STROKING LOADS

Energy Absorber Test Series	Average Load (lb)	Standard Deviation (lb)
Fielded -1	1851	133
Fielded -2	771	121
Fielded -3	1843	140
New -1	1930	116
New -2	773	73
New -3	1926	145

8.5 ARA POSTTEST INSPECTION

There was no visible evidence of significant corrosion on the exterior of the extended tubes. One of the middle energy absorbers from each aircraft was cut open and inspected. Energy absorber S/N 102 had an area of slight corrosion on the interior of the tube (see Figure 25).

After the stroked energy absorbers had been in dry storage for approximately four months, some of the extended tubes began to show signs of corrosion (rust). This indicates that stroking of the energy absorbers either removed the corrosion protection from the tubes or that corrosion protection relies entirely on the oil that is packed in the assembly.

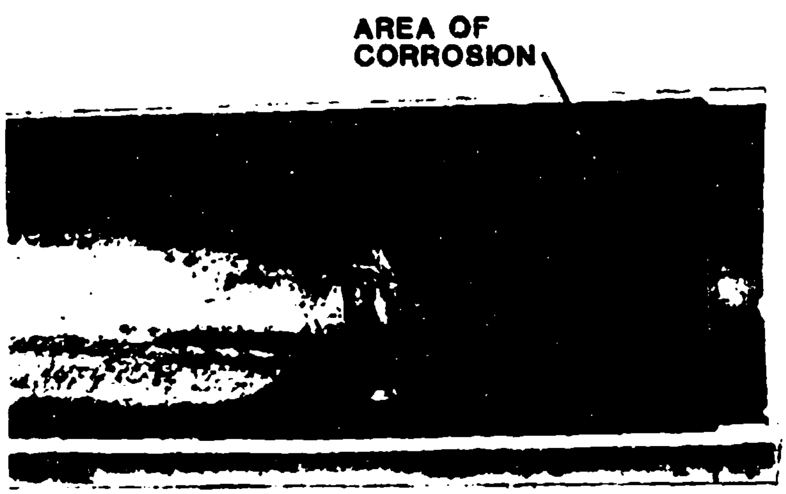


FIGURE 25. EXAMPLE OF INTERIOR CORROSION - ARA CREW SEAT ENERGY ABSORBERS.

9.0 SIMULA/NORTON CREW SEAT ENERGY ABSORBER TEST RESULTS

9.1 REQUIREMENTS

Energy absorber load-deflection requirements as specified on Simula Drawing No. 100014 are as follows:

- Desired Static Stroking Load: 1206 ± 100 lb
- Minimum Required Stroke: 17.0 in.

The drawing does not specify the desired dynamic stroking load or the stroke allowed to reach load. According to the static qualification report for this seat (Reference 1), dynamic stroking increased the load by an average of 13 percent, and a stroke of 0.3 in. was required to reach steady state stroking load. This translates to a desired dynamic stroking load of 1363 ± 113 lb. The desired load-deflection corridors are shown in Figure 26.

9.2 SIMULA/NORTON CREW SEAT ENERGY ABSORBER STATIC TEST RESULTS

9.2.1 New Energy Absorbers

Plots of the static test results for the new Simula/Norton energy absorbers are shown in Figure 27. Both energy absorbers stroked within the desired corridor.

9.2.2 Fielded Energy Absorbers

Plots of the static test results for the fielded Simula/Norton energy absorbers are shown in Figure 28. Both energy absorbers stroked within the desired corridor. Energy absorber S/N 014 had a slight load increase at the end of the stroke which was caused by the inversion tube rubbing on the housing.

9.3 SIMULA/NORTON CREW SEAT ENERGY ABSORBER DYNAMIC TEST RESULTS

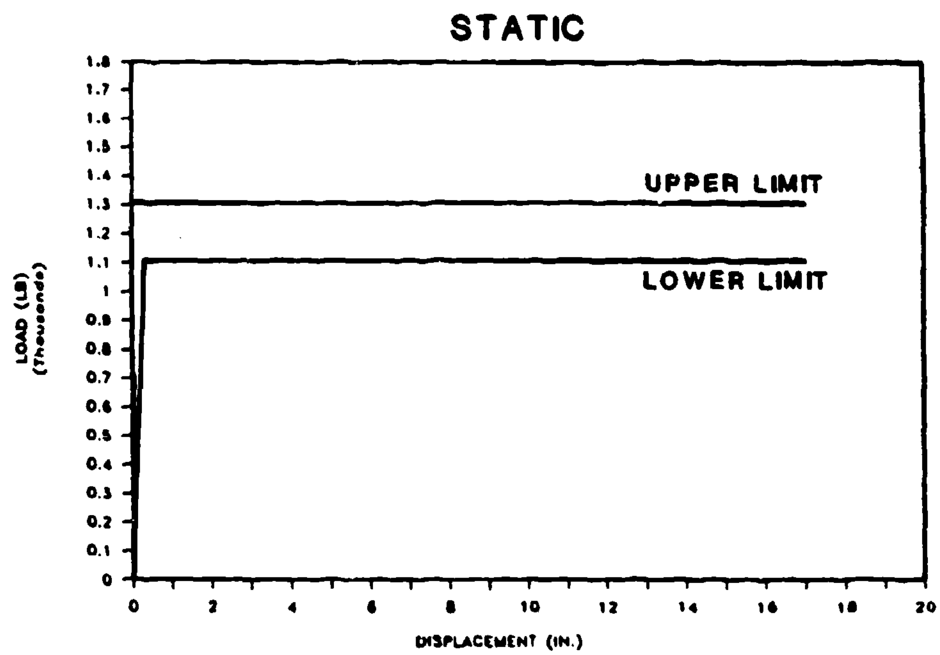
These energy absorbers were stroked at an average velocity between 9.6 and 14.1 ft/sec.

9.3.1 New Energy Absorbers

An example of dynamic test results for a new Simula/Norton energy absorber is shown in Figure 29. All six of the new energy absorbers stroked within the desired corridor. One energy absorber had a small spike outside the corridor at the start of the stroke. Plots of dynamic test results for these energy absorbers can be found in Appendix D.

9.3.2 Fielded Energy Absorbers

Examples of dynamic test results for the fielded Simula/Norton energy absorbers are shown in Figure 30. All of the fielded energy absorbers stroked within the desired limits except S/N 013. Energy absorber S/N 046 had the highest stroke. Note the brief initial spike outside the corridor at the



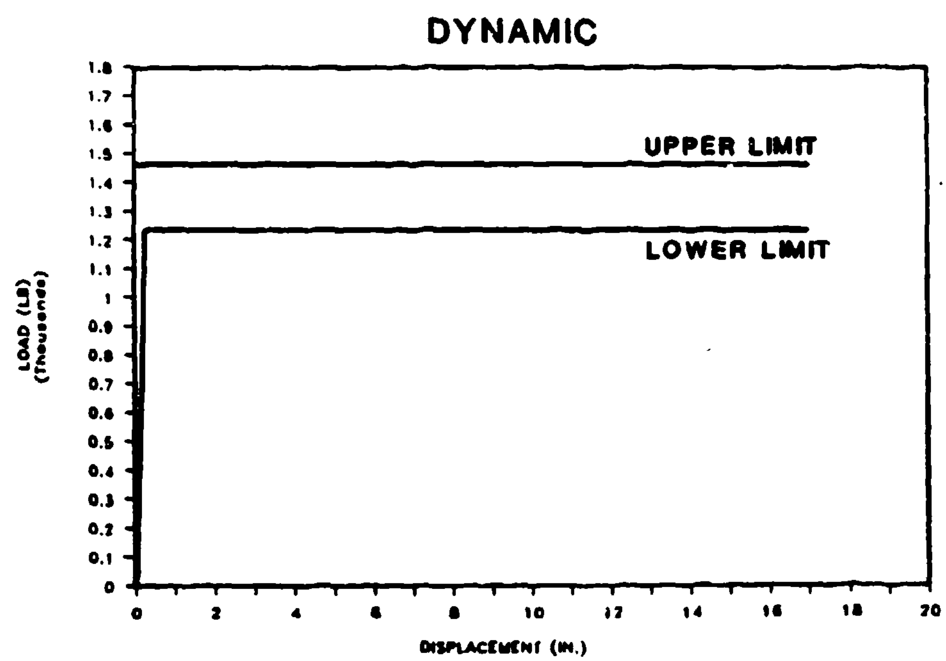
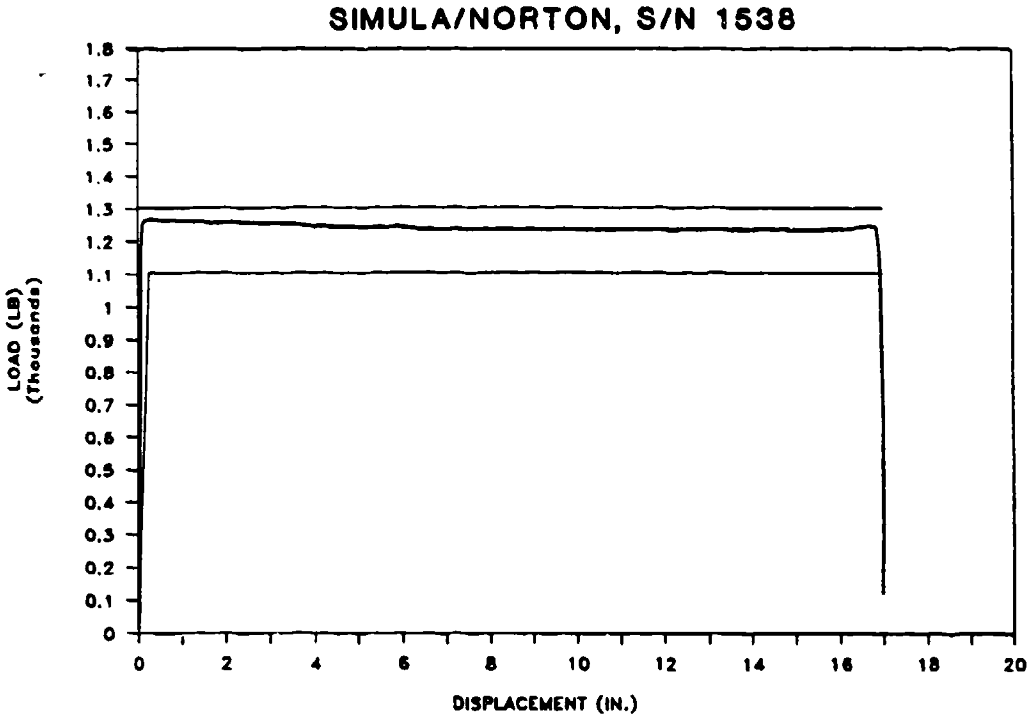


FIGURE 26. SIMULA/NORTON ENERGY ABSORBERS LOAD-DISPLACMENT CORRIDORS.



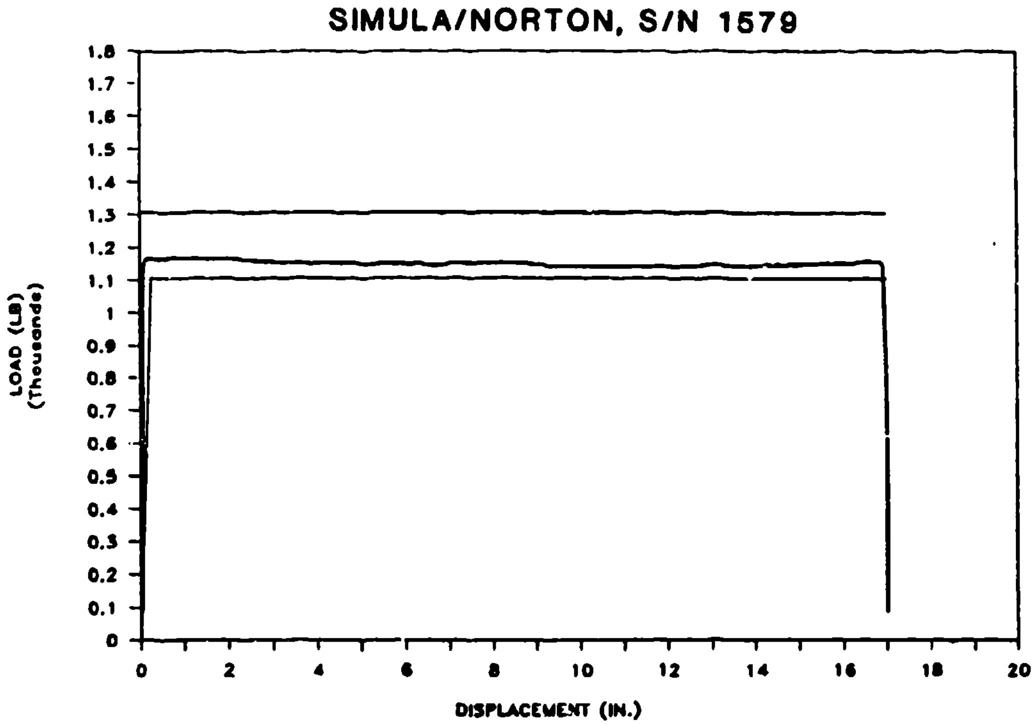
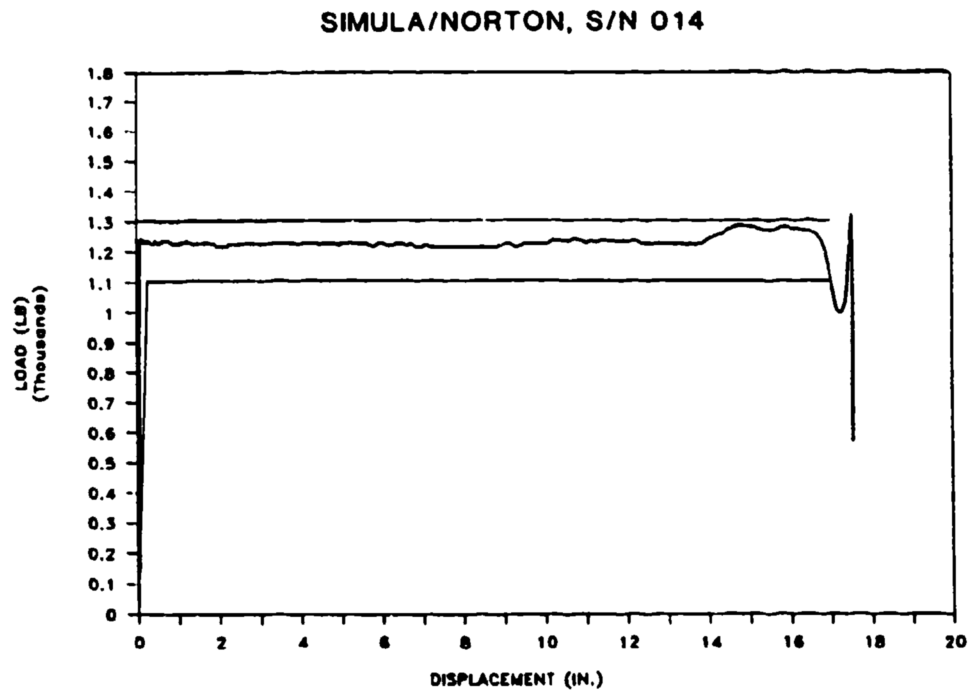


FIGURE 27. STATIC TEST RESULTS - SIMULA/NORTON CREW SEAT, NEW ENERGY ABSORBERS.



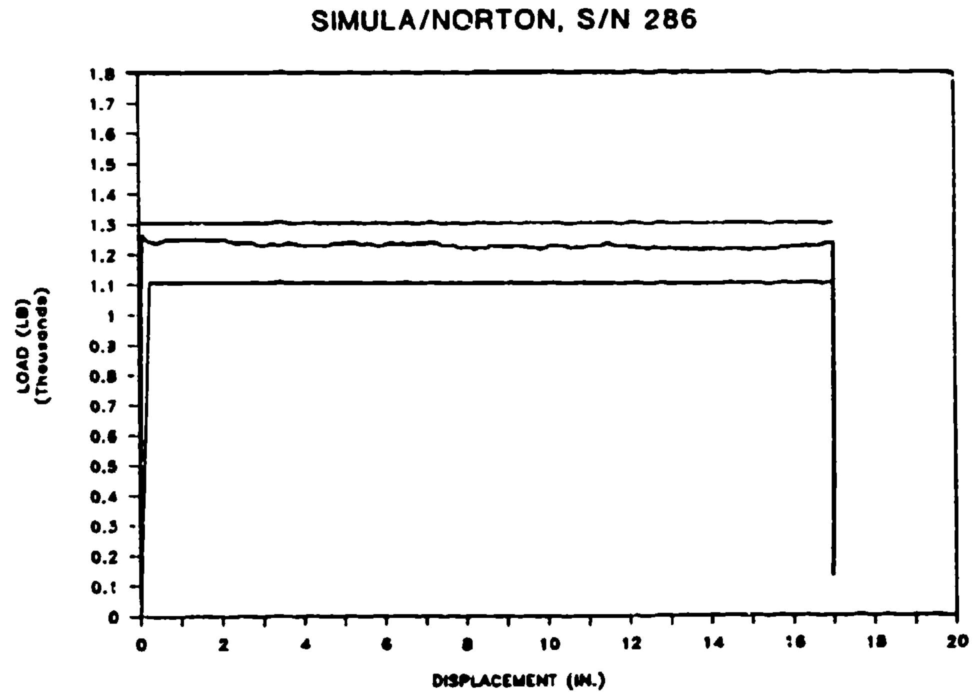


FIGURE 28. STATIC TEST RESULTS - SIMULA/NORTON CREW SEAT, FIELDED ENERGY ABSORBER.

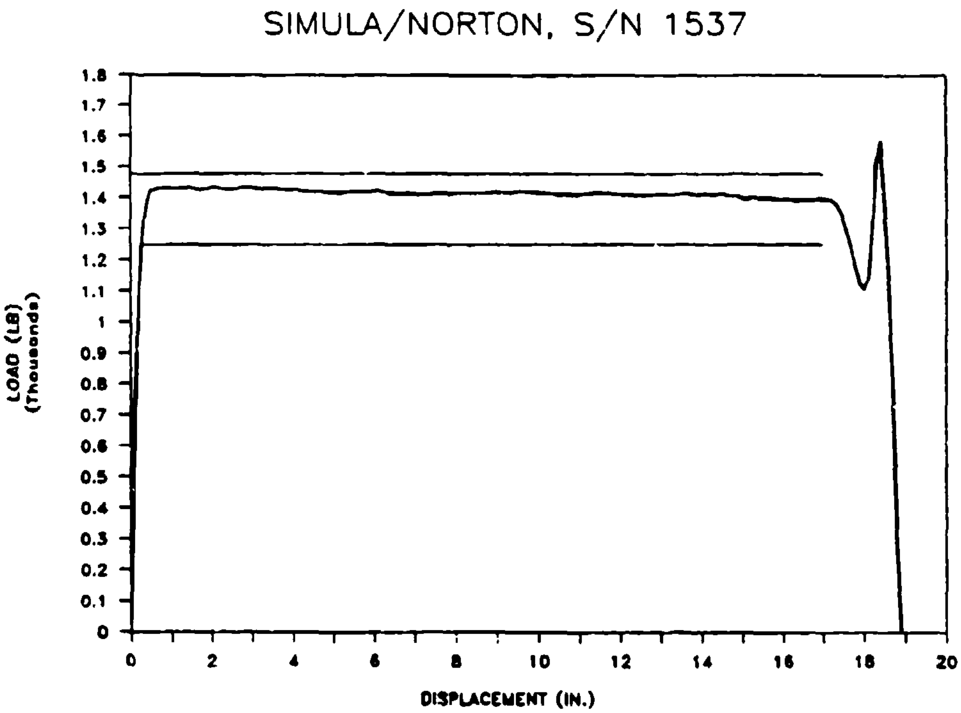


FIGURE 29. TYPICAL DYNAMIC TEST RESULT - SIMULA/NORTON CREW SEAT, NEW ENERGY ABSORBER.

start of stroke: a total of three energy absorbers had a similar minor spike at the start of stroke. This spike was noted during seat qualification testing and is considered acceptable (Reference 1).

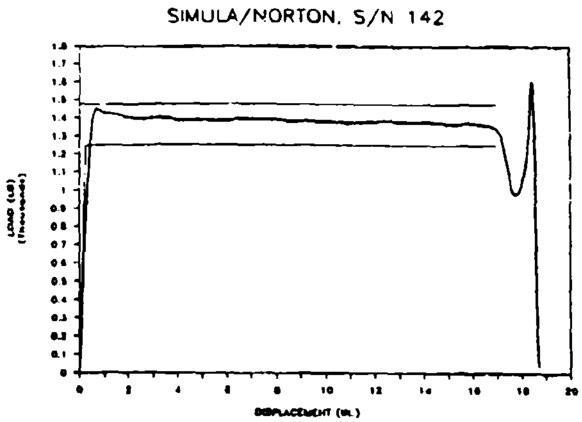
9.4 SIMULA/NORTON CREW SEAT ENERGY ABSORBER TEST RESULT SUMMARY

All Simula/Norton energy absorbers met the manufacturer's requirements except for S/N 13 from aircraft 77-22728. (See Table 11 for a complete test summary.) Table 12 shows the calculated average stroking loads and the calculated standard deviation for each attenuator test series.

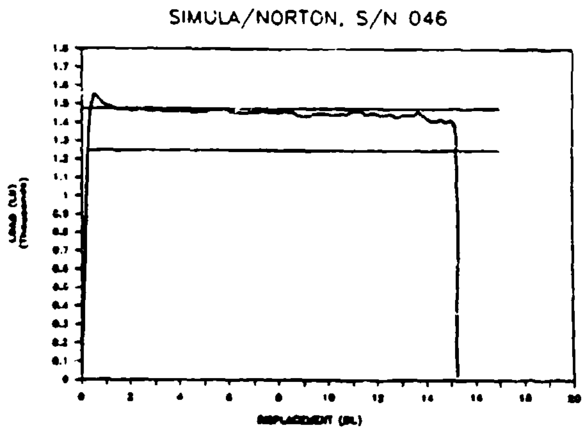
9.5 SIMULA/NORTON CREW SEAT POSTTEST INSPECTION

Eleven out of 24 energy absorbers showed visible evidence of corrosion. Two had relatively severe pitting, two had relatively large corroded patches, and seven had faint rust-colored rings (Figure 31).

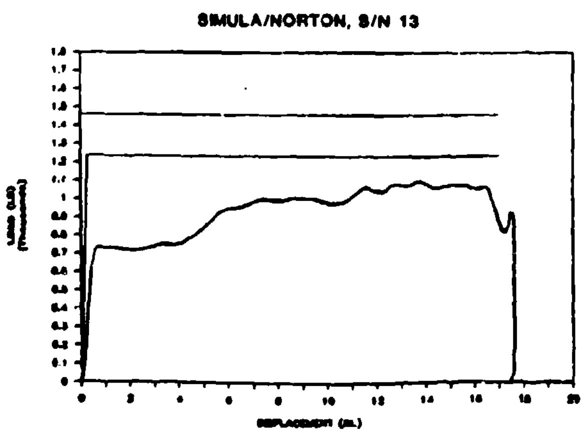
Table 13 summarizes the information on energy absorbers that experienced corrosion. All the aircraft spent approximately 6 years at Fort Campbell, Kentucky. Aircraft 78-22973 spent its entire tour there and exhibited the



a. TYPICAL



b. HIGHEST



c. LOWEST

FIGURE 30. DYNAMIC TEST EXAMPLES - SIMULA/NORTON CREW SEAT, FIELDED ENERGY ABSORBERS.

TABLE 11. SIMULA/NORTON CREW SEAT ENERGY ABSORBER TEST RESULTS SUMMARY

Energy Absorber S/N	Aircraft T/N	Test Type Static	Test Type Dynamic	Energy(1) Absorbed (in.-lb)	Average Stroking Load (lb)	Meets Manufacturer Requirements Yes	Meets Manufacturer Requirements No	Appendix D Figure No.
13	77-22728		X	15,856	932		X	D-1a
14		X		20,095	1,232	X		D-1b
46			X	24,471	1,444	X(2)		D-2a
47			X	23,691	1,390	X		D-2b
142	78-22966		X	23,433	1,374	X		D-3b
143			X	22,944	1,352	X		D-3a
188			X	23,960	1,409	X		D-4a
1516			X	23,715	1,395	X		D-4b
203	78-22973		X	24,384	1,433	X		D-6a
204			X	24,438	1,436	X		D-6b
224			X	23,532	1,383	X		D-5b
225			X	22,900	1,401	X		D-5a
282	78-22990		X	23,799	1,397	X		D-8b
283			X	24,261	1,425	X		D-8a
296			X	24,464	1,318	X		D-7b
297			X	22,376	1,312	X		D-7a
167	78-22991		X	24,173	1,418	X(2)		D-10b
168			X	24,468	1,433	X(2)		D-10a
286		X		20,875	1,228	X		D-9b
287			X	23,691	1,393	X		D-9a
1537	N/A New		X	24,121	1,416	X		D-11a
1538		X		21,052	1,239	X		D-11b
1540			X	24,429	1,434	X(2)		D-12a
1542			X	24,121	1,416	X		D-12b
1579		X		19,487	1,147	X		D-13a
1580			X	22,297	1,345	X		D-13b
1585			X	22,901	1,342	X		D-14a
1586			X	21,954	1,296	X		D-14b

(1) Energy absorbed based on 17.0 in. stroke. If during dynamic testing the stroke stopped short of 17.0 in., the load was assumed constant for the remaining stroke. Calculated energy ranges: Static - 18,684 to 22,202 in.-lb
Dynamic - 21,094 to 25,092 in.-lb

(2) Load exceeded tolerance at start of stroke and remained within limits for remainder of stroke.

TABLE 12. SIMULA/NORTON CREW SEAT ENERGY ABSORBER AVERAGE STROKING LOADS

Energy Absorber Test Series	Average Load (lb)	Standard Deviation (lb)
Fielded Static	1230	3
New Static	1193	65
Fielded Dynamic	1369	115
New Dynamic	1375	55

TABLE 13. SIMULA/NORTON CREW SEAT ENERGY ABSORBER CORROSION SUMMARY

Energy Absorber S/N	Aircraft T/N	Type of Corrosion
13	77-22728	Patch
14	77-22728	Patch
47	77-22728	Ring
142	78-22986	Pitting
188	78-22986	Ring
204	78-22973	Pitting
224	78-22973	Ring
225	78-22973	Ring
167	78-22991	Ring
168	78-22991	Ring
286	78-22991	Ring

worst corrosion. Aircraft 77-22728 spent only 2 years in the Fort Campbell environment and shows no signs of corrosion. See Appendix A for complete aircraft histories.

All of the energy absorbers with corrosion had acceptable load-deflection characteristics and total energy absorption except S/N 013. This energy absorber did have a corrosion patch but it was only in a localized area. S/N 014 had a larger corrosion patch and had acceptable stroking characteristics, indicating that the corrosion was not a factor for stroking performance.

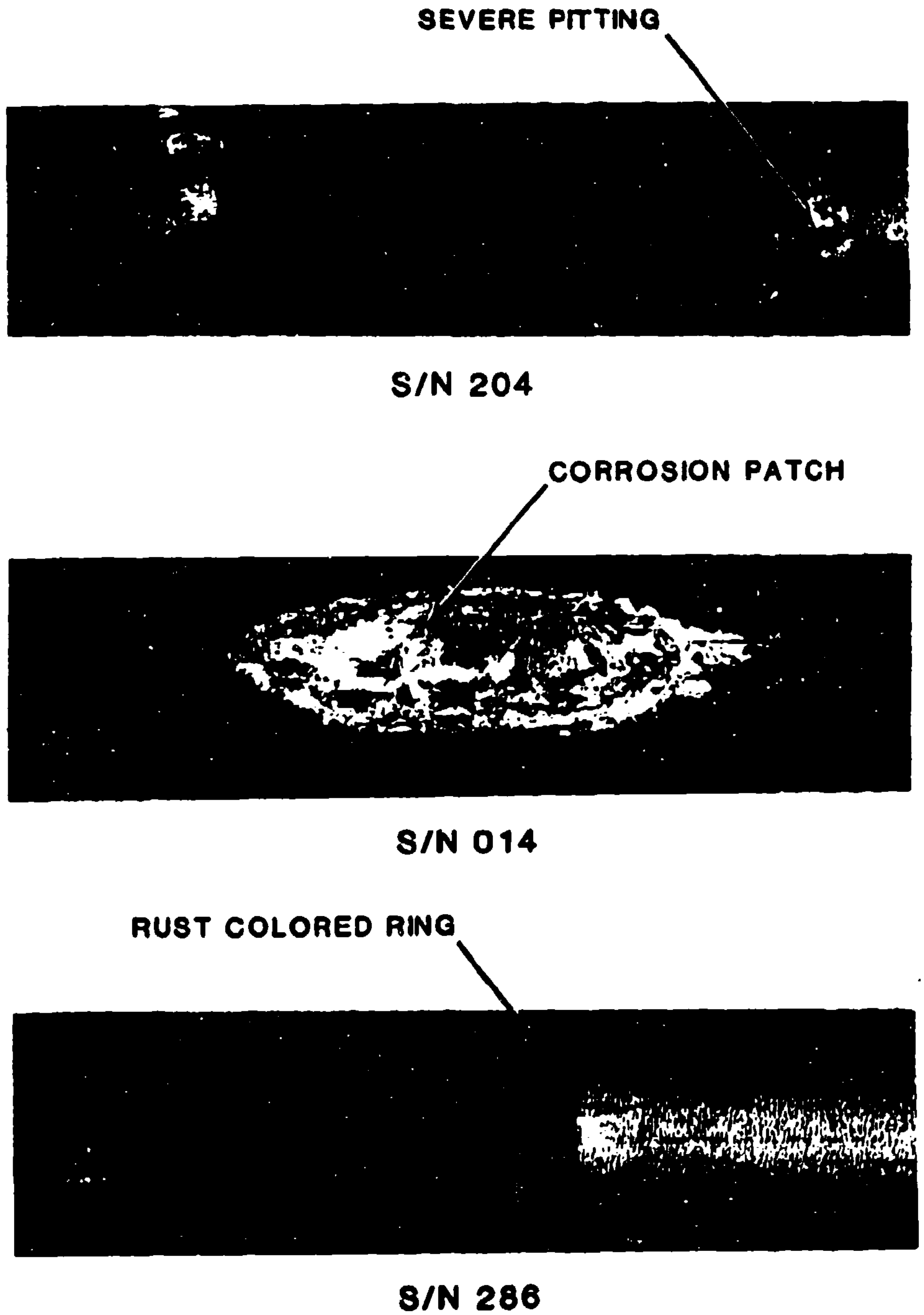


FIGURE 31. SIMULA/NORTON CREW SEAT ENERGY ABSORBER CORROSION EXAMPLES.

10.0 INJURY EVALUATION

Computer program SOM-LA (Seat Occupant Model - Light Aircraft) was used to evaluate the potential for injury resulting from energy absorbers that were out of specification. Program SOM-LA was developed under contract to the FAA and is fully described in Reference 2. The standard edition of SOM-LA includes a 12-segment occupant model with 29 degrees of freedom and a finite element model of the seat structure. Characteristics for either a human occupant or an anthropomorphic dummy are included. Interface loads between the occupant and floor, seat restraint, and seat cushions are provided. An option in the program allows modeling of a semirigid seat frame with a unidirectional constant load stroking seat. For this contract, a specially modified version of SOM-LA was used which allowed omnidirectional stroking of the seat with variable load stroking energy absorbers. This permitted inputting the actual force-deflection characteristics of the energy absorbers as determined from the testing.

Modeling was conducted with a 50th-percentile human occupant for a pure vertical impact. The input pulse and occupant weights used are shown in Figure 32. The outputs from the model were the DRI (Dynamic Response Index), pelvis vertical acceleration/duration plot (Eiband curve), maximum spinal compression load, and seat vertical stroke.

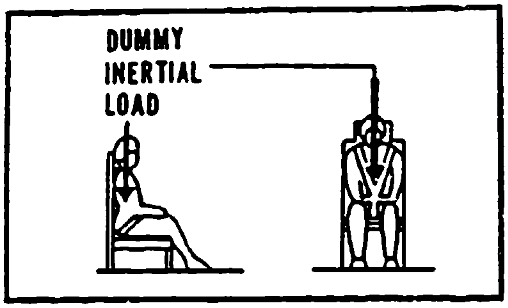
The DRI has been shown to be effective in predicting spinal injuries in ejection seats as shown in Figure 33. The DRI is calculated using a single lumped-mass, damped-spring model to determine the maximum deformation of the spine and associated force. However, it should be remembered that this is a simple model of a complex dynamic system and a helicopter pilot leaning forward in his seat might be expected to respond differently from an upright, well-restrained ejection seat occupant.

The Eiband curves were developed based on experimental test results (Reference 4) and are the generally accepted benchmark to determine human tolerance levels. The experiments used to generate these curves used a uniform peak acceleration plateau of various magnitudes and durations. To compare the SOM-LA acceleration results to the Eiband limits, the summation of all times for any given acceleration was used as shown in Figure 34. The Eiband limits were selected according to the Aircraft Crash Survival Design Guide (Reference 3) as shown in Figure 35. Also shown is the location of 23 G at 25 msec as specified as the maximum limit in MIL-S-58095(A) (Reference 5).

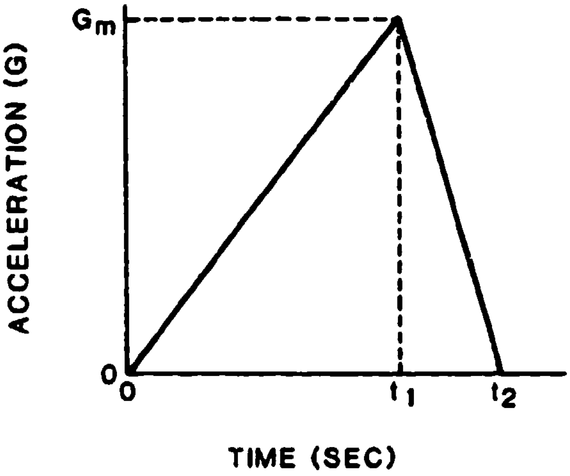
10.1 TROOP SEAT INJURY EVALUATION

10.1.1 Model Validation

The model was validated by comparison of predicted results to test data for the Simula S-70A-9 Royal Australian Air Force (RAAF) troop seat. This seat is similar to the Sikorsky troop seat but differs in occupant size (300 lb) and energy absorber stroking loads (1400 lb). Results of the validation are shown in Figure 36.



IMPACT ATTITUDE

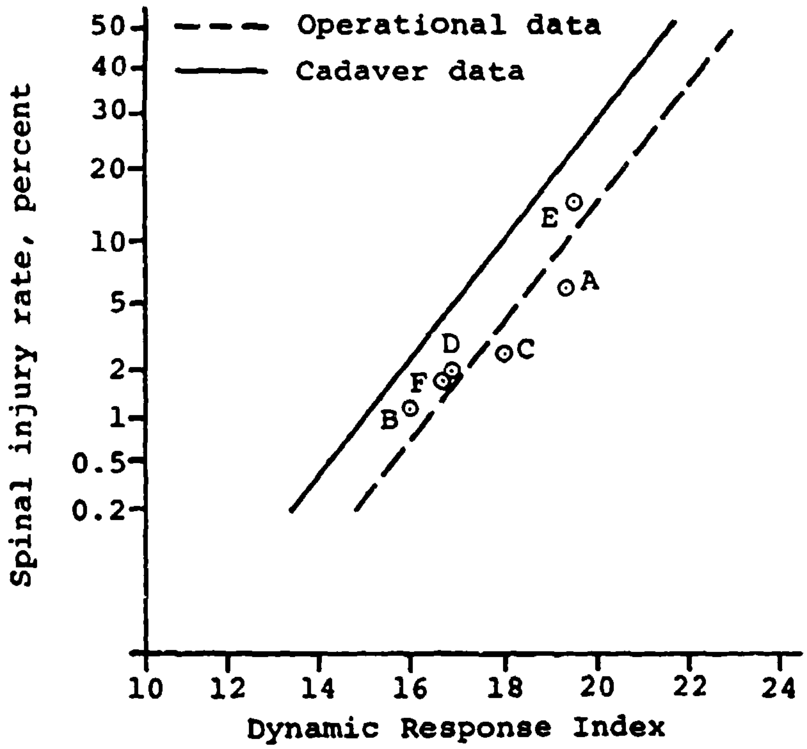


PULSE SHAPE

	CREW SEATS	TROOP SEAT
t_1 (SEC)	0.040	0.060
t_2 (SEC)	0.055	0.078
G_m (G)	48.0	34.0
VELOCITY CHANGE (FT/SEC)	42.5	42.6
OCCUPANT* WEIGHT (LB)	181.1	196.6

*INCLUDES ALL CLOTHING AND EQUIPMENT

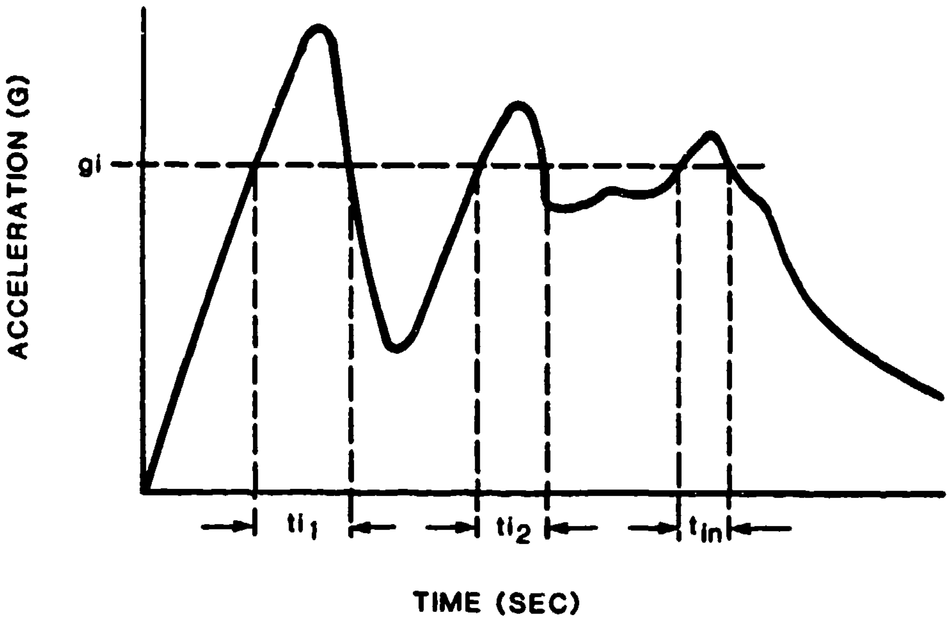
FIGURE 32. SOM-LA MODEL PARAMETERS.



Aircraft type	Nonfatal ejections
A*	64
B*	62
C	65
D*	89
E	33
F	48

*Denotes rocket catapult

FIGURE 33. PROBABILITY OF SPINAL INJURY ESTIMATED FROM LABORATORY DATA COMPARED TO EJECTION SEAT OPERATIONAL EXPERIENCE. (FROM REFERENCE 3)



$$ti = ti_1 + ti_2 + ti_n$$

FIGURE 34. PROCEDURE FOR SUMMING DURATION OF ACCELERATION EXCEEDING THE LIMIT, gi.

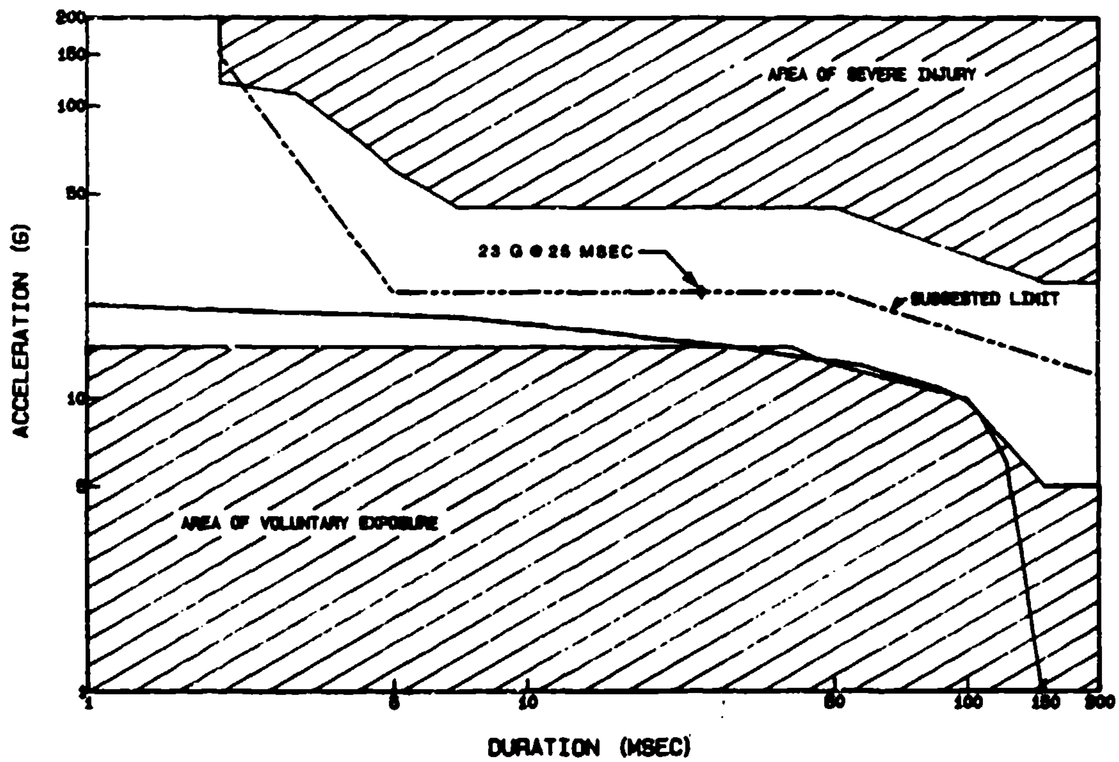
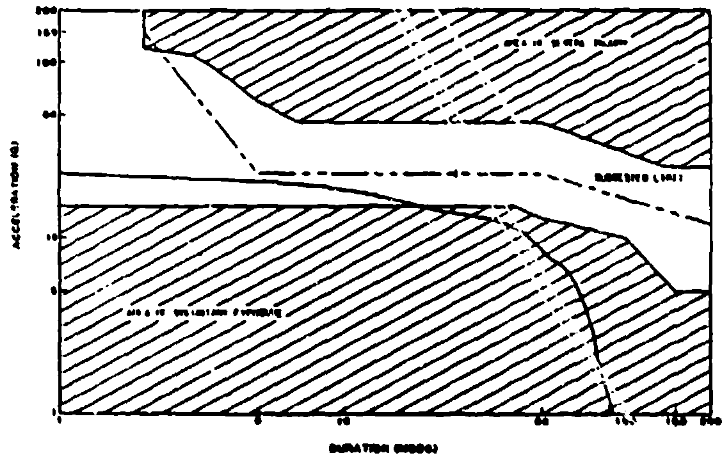


FIGURE 35. HUMAN TOLERANCE LEVELS FOR VERTICAL ACCELERATION.

SOM-LA PREDICTION



	SOM-LA	TEST
DRI	20.74	N/A
MAX. SPINAL LOAD (LB)	2,037	N/A
VERTICAL STROKE (IN.)	12.0	12.1

TEST RESULTS

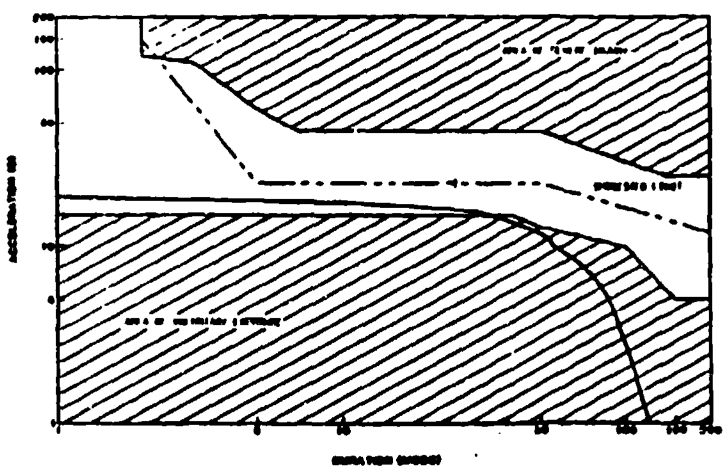


FIGURE 36. COMPARISON OF SOM-LA PREDICTION AND TEST RESULTS FOR THE S-70A-9 RAAF TROOP SEAT.

The test dummy did not have provisions for spinal load measurement; however, the prediction for pelvis vertical acceleration and vertical stroke is acceptable. The DRI is a calculated value and was not measured during testing.

10.1.2 Troop Seat Model Results

A total of five seats were modeled, as shown in Table 14. Run Nos. 1 and 2 are for the specification nominal stroking load of 1300 lb and for a constant load of 1050 lb, which is consistent with tests of new energy absorbers. The other three runs cover the extremes of the tested energy absorbers. The plots for these energy absorbers are shown in Figure 37. A run was not made with both energy absorbers failing.

The SOM-LA model results are shown in Table 15 and Figure 38.

TABLE 14. TROOP SEATS MODELED WITH PROGRAM SOM-LA

Run No.	Aircraft T/N	Seat No.	Description
1	N/A	N/A	1300 lb constant load
2	N/A	N/A	1050 lb constant load
3	78-22971	4	Highest stroking loads
4	78-22971	9	Lowest stroking loads (no failure)
5	78-22971	8	Typical seat with one failed energy absorber

TABLE 15. TROOP SEAT SOM-LA MODEL RESULTS

Run No.	Maximum DRI	Maximum Spinal Load (lb)	Vertical Stroke (in.)	Description
1	31.98	2594	9.77	1300 lb constant load
2	30.29	2430	11.69	1050 lb constant load
3	31.31	2629	10.66	Highest stroking load
4	29.45	2440	12.82	Lowest stroking load (no failure)
5	29.81	2517	15.34*	Typical seat with one failed energy absorber

*Stroking load assumed constant past 14 in.

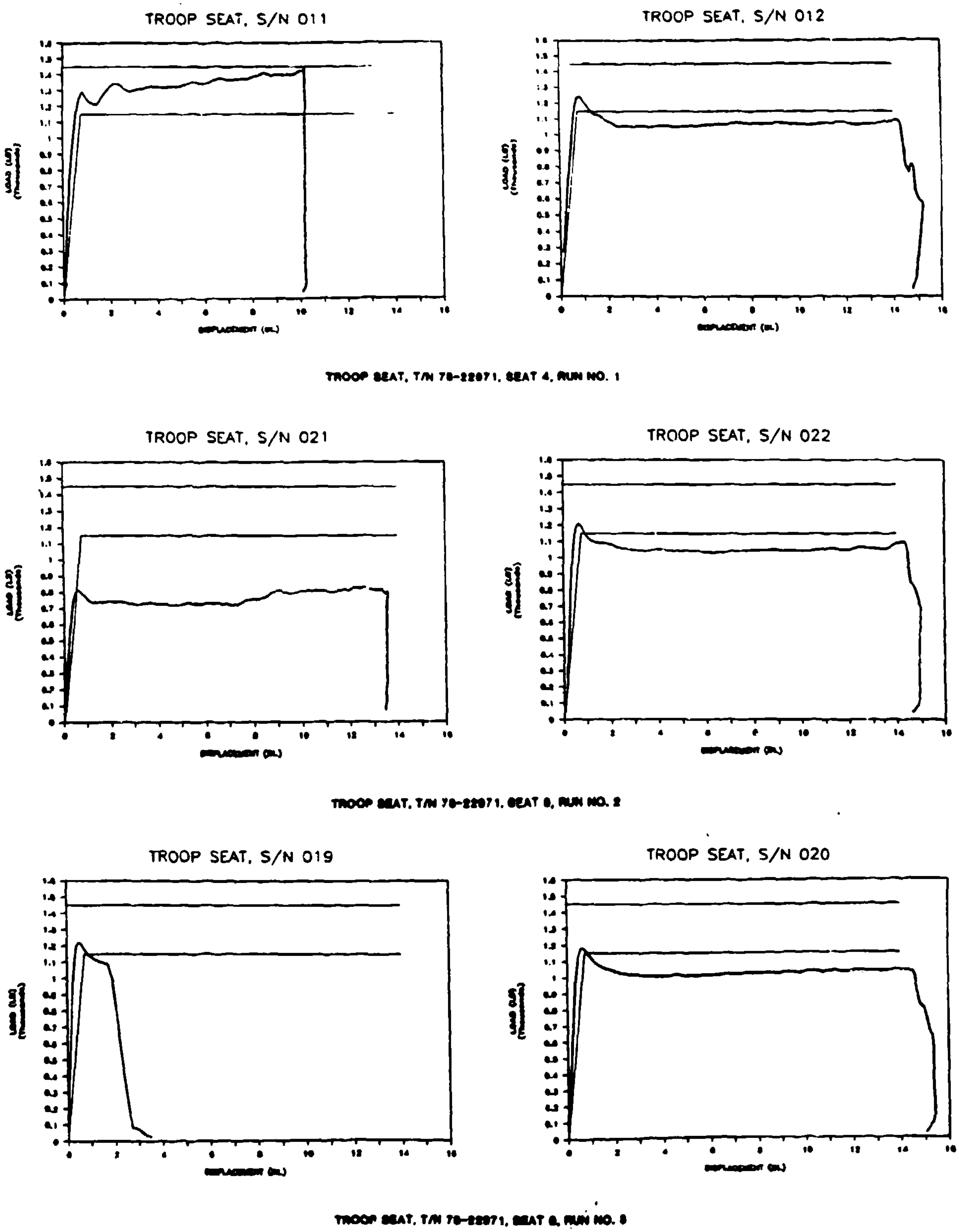


FIGURE 37. TROOP SEAT ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS FOR SOM-LA MODELS.

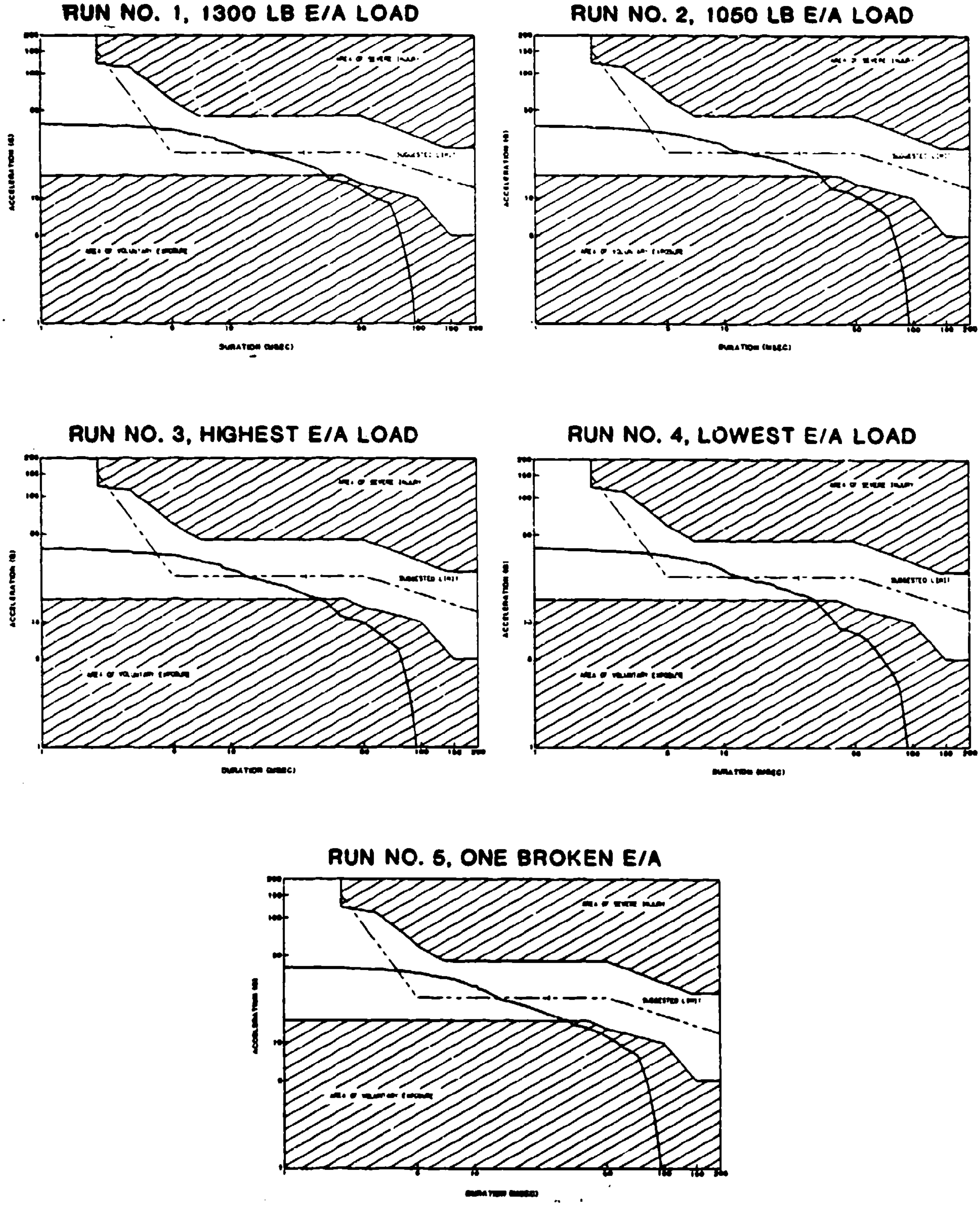


FIGURE 38. EIBAND PLOTS FOR TROOP SEAT SOM-LA MODEL PELVIS VERTICAL ACCELERATION.

For these models, the equipment weight of a 33.3 lb backpack was assumed as an additional occupant mass on the upper torso, which increased the spinal compression load by approximately 1000 lb (based on model prediction of a short duration upper torso acceleration of 30G at time of peak spinal load). If the backpack were to bottom out on the seat frame, or be otherwise supported, the spinal load would be decreased accordingly.

10.2 ARA CREW SEAT INJURY EVALUATION

10.2.1 Model Validation

This seat had not been modeled with program SOM-LA before, so a special model was developed. Validation was conducted using data from the Civil Aeromedical Institute (CAMI) dynamic test 83-068, which was a vertical impact of 42.5 ft/sec at 44 G with a 50th-percentile dummy. The model validation was limited in scope and essentially performed as a sanity check rather than an extensive correlation with test data. It would not have been practical to perform an extensive validation since the actual load-deflection characteristics of the tested seat energy absorbers were unknown. A comparison of the test and SOM-LA results are shown in Figure 39. Both predict severe injury according to the Eiband criteria.

10.2.2 ARA Crew Seat Model Results

Four seats were modeled, as shown in Table 16.

TABLE 16. ARA CREW SEATS MODELED WITH PROGRAM SOM-LA

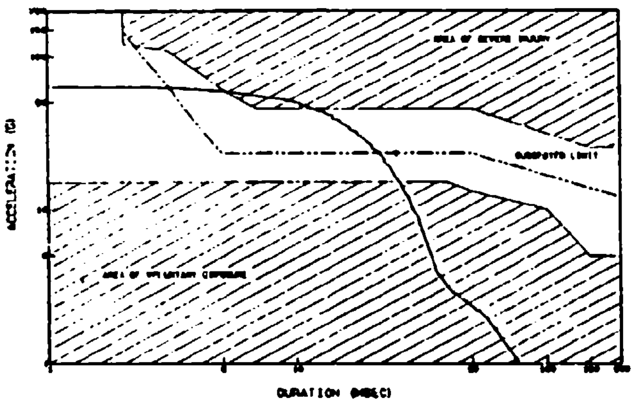
Run No.	Aircraft Tail No.	Seat S/N	Description
1	N/A	N/A	Theoretical nominal loads
2	81-23597	*	Lowest -2 energy absorber loads
3	81-23598	043	Highest -2 energy absorber loads
4	81-23619	081	Highest -1 energy absorber loads

*Name placard missing.

Seats were selected primarily for the -2 energy absorbers since they predominantly control the vertical stroking loads (the other two sets of energy absorbers are essentially pivot arms). The other seat selected had -1 energy absorbers which stroked relatively low at the start and relatively high at the end. Plots of all the energy absorbers modeled can be found in Figures 40 through 42.

The results of the SOM-LA modeling are shown in Table 17 and Figure 43.

SOM-LA PREDICTION
NOMINAL E/A LOADS



	SOM-LA	TEST
DRI	42.25	N/A
MAX. SPINAL LOAD (LB)	2,330	2,240
VERTICAL STROKE (IN.)	2.8	5.0

CAMI TEST 83-068

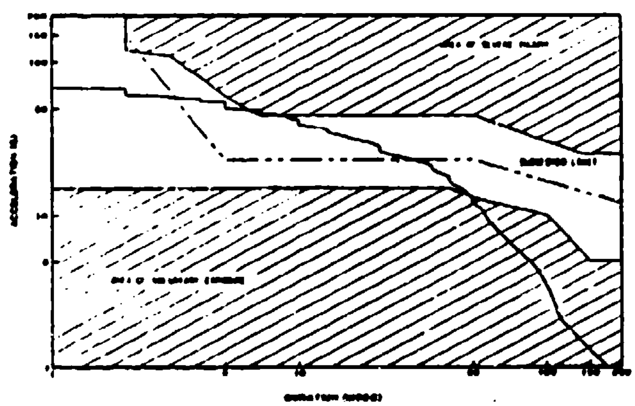


FIGURE 39. COMPARISON OF SOM-LA PREDICTION AND CAMI TEST RESULTS FOR ARA CREW SEAT.

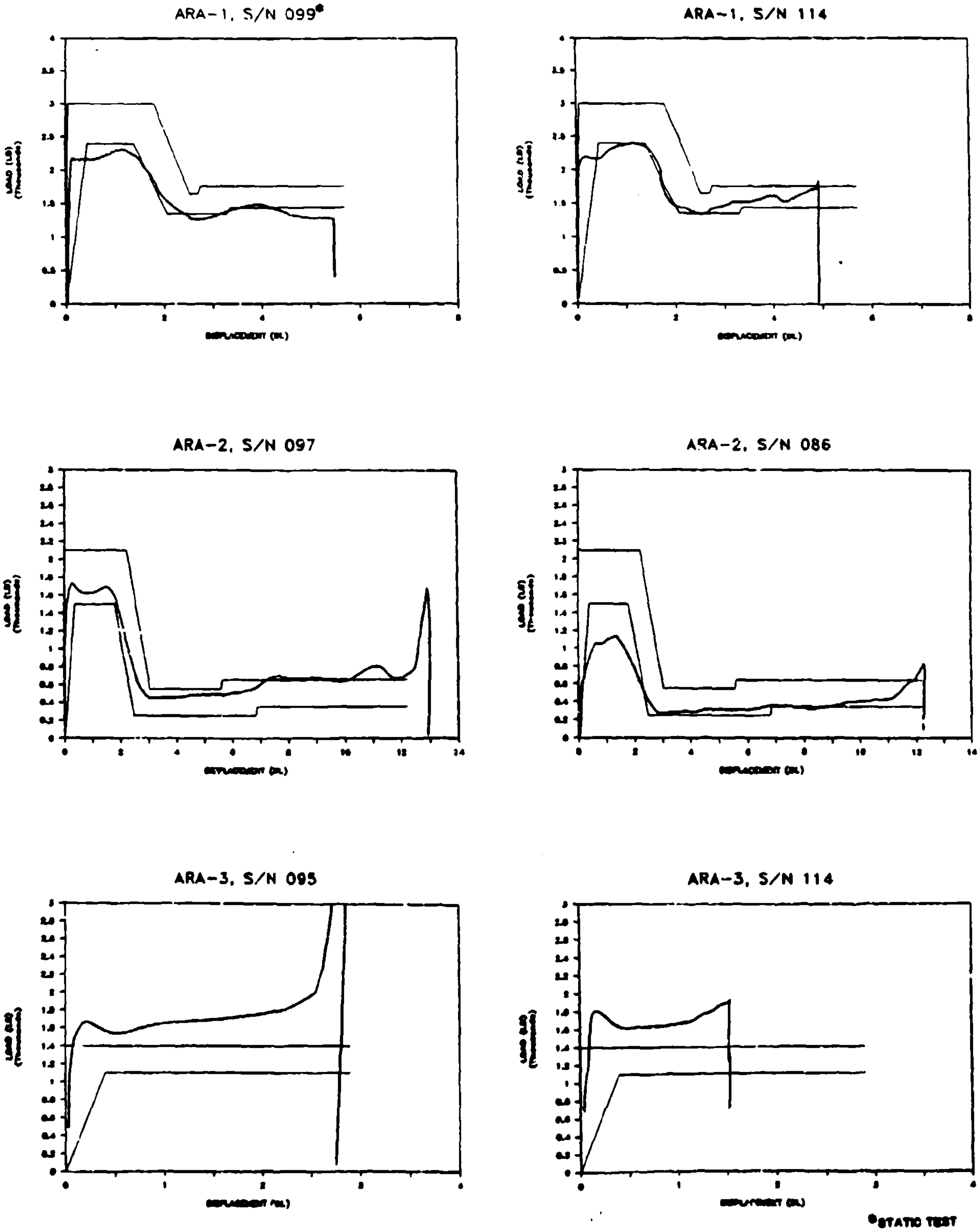


FIGURE 40. ARA CREW SEAT LOWEST -2 ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS, COPILOT SEAT, T/N 81-23597, SOH-LA MODEL 2.

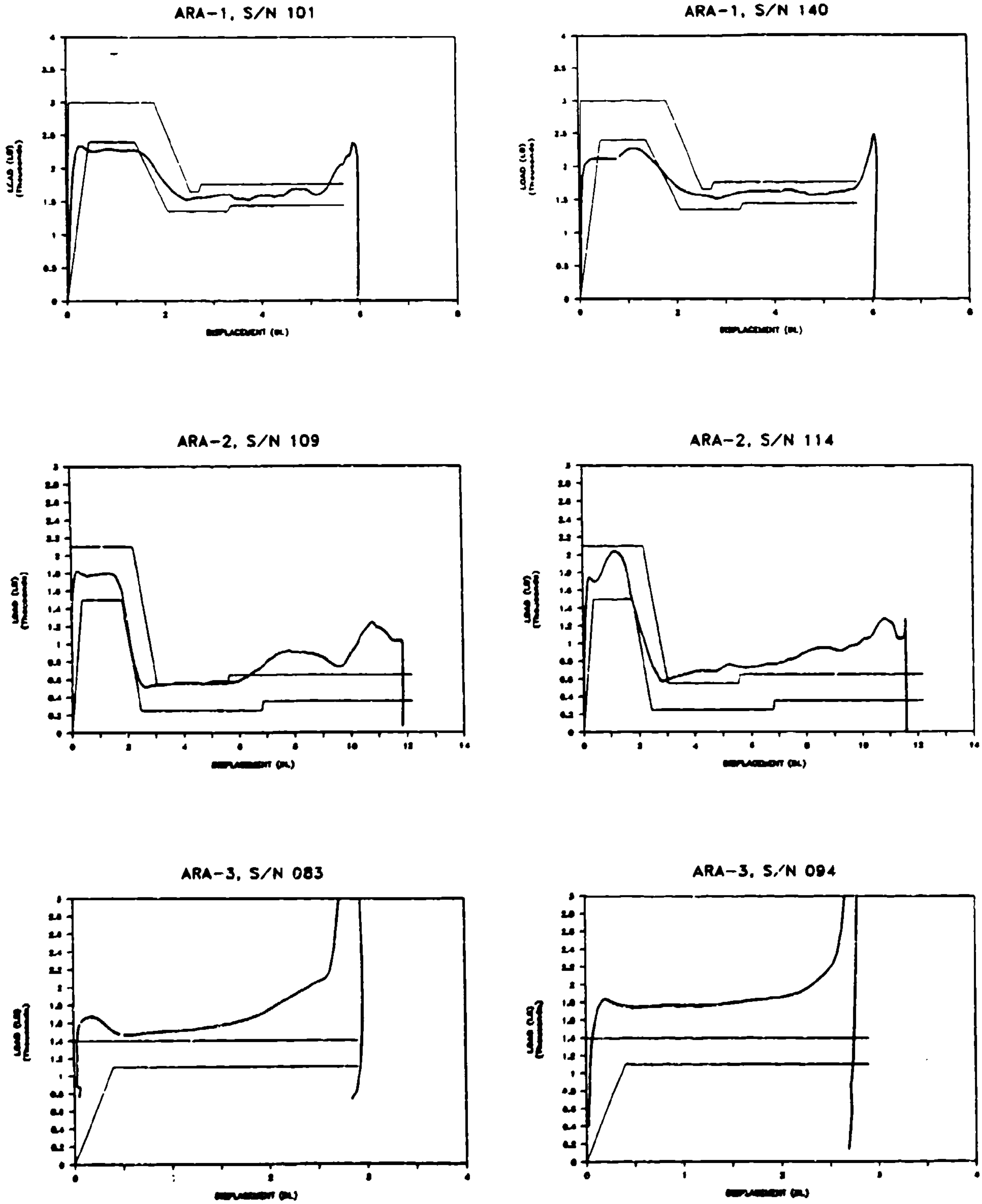


FIGURE 41. ARA CREW SEAT HIGHEST -2 ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS, SEAT S/N 043, T/N 81-23598, SOM-LA MODEL 3.

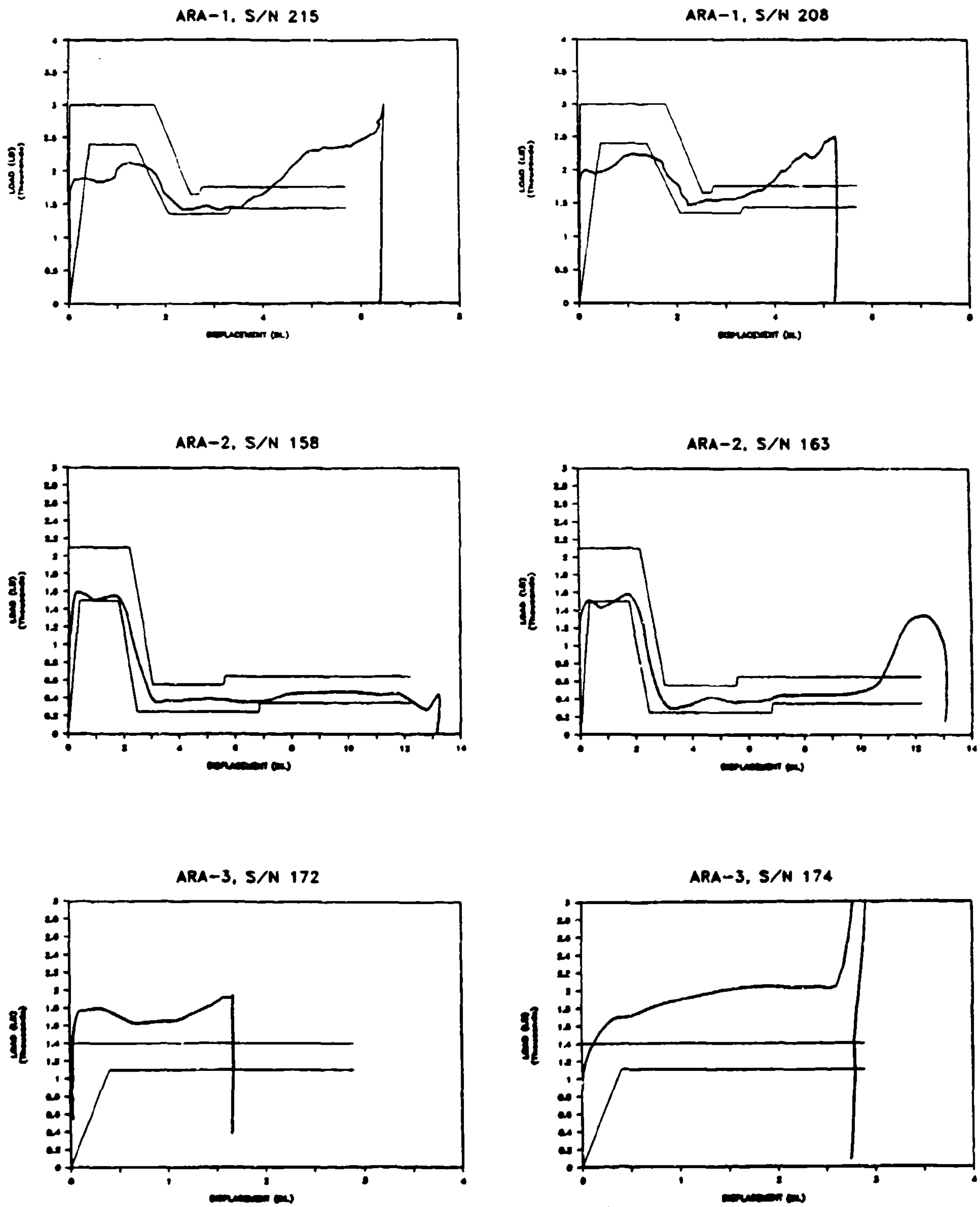


FIGURE 42. ARA CREW SEAT HIGHEST -1 ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS, SEAT S/N 081, T/N 81-23619, SOM-LA MODEL 4.

TABLE 17. ARA CREW SEAT SOM-LA MODEL RESULTS

Run No.	Maximum DR_z	Maximum Spinal Load (lb)	Vertical Stroke (in.)	Description
1	42.25	2830	2.8	Theoretical nominal loads
2	39.39	2720	4.5	Lowest -2 energy absorber loads
3	42.03	2820	2.6	Highest -2 energy absorber loads
4	40.65	2759	4.0	Highest -1 energy absorber loads

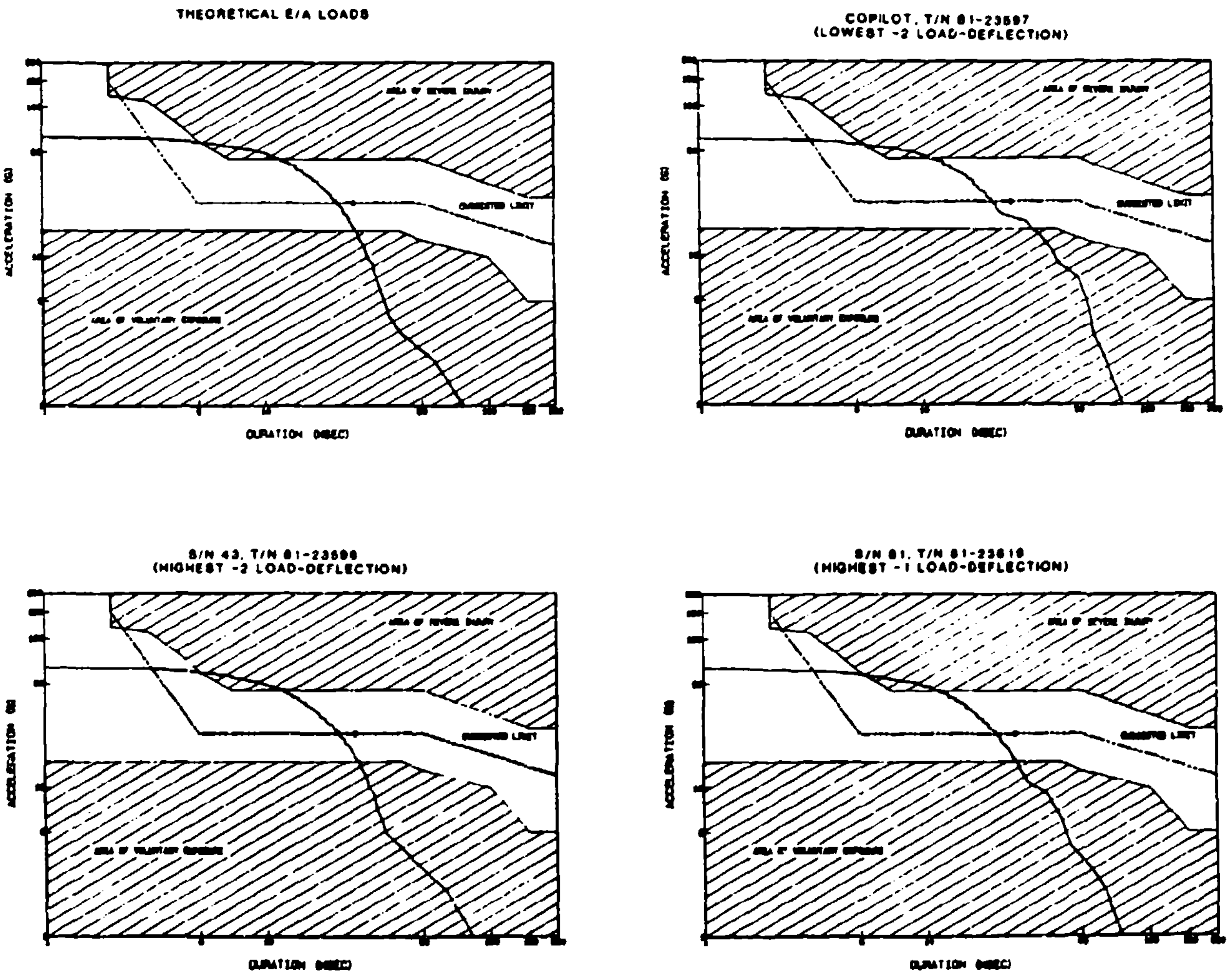


FIGURE 43. EIBAND PLOTS FOR ARA CREW SEAT SOM-LA MODEL PELVIS VERTICAL ACCELERATION.

10.3 SIMULA/NORTON CREW SEAT INJURY EVALUATION

10.3.1 Model Validation

Extensive validation has been performed for the SOM-LA model of the Simula/Norton crew seat and can be found in Reference 2. This seat is more readily modeled since the guide tubes force the seat to stroke along a known path.

10.3.2 Simula/Norton Crew Seat Model Results

Three seats were modeled, as shown in Table 18. The energy absorber load-deflection characteristics are shown in Figure 44. The model results are shown in Table 19 and Figure 45. Note that the seat with the lowest energy absorber loads would have required approximately 3.7 in. more stroke as compared to the nominal stroking loads.

TABLE 18. SIMULA/NORTON CREW SEATS MODELED WITH PROGRAM SOM-LA

Run No.	Aircraft T/N	Seat S/N	Description
1	77-22728	04	Lowest energy absorber loads
2	78-22973	82	Highest energy absorber loads
3	N/A	N/A	Nominal energy absorber loads

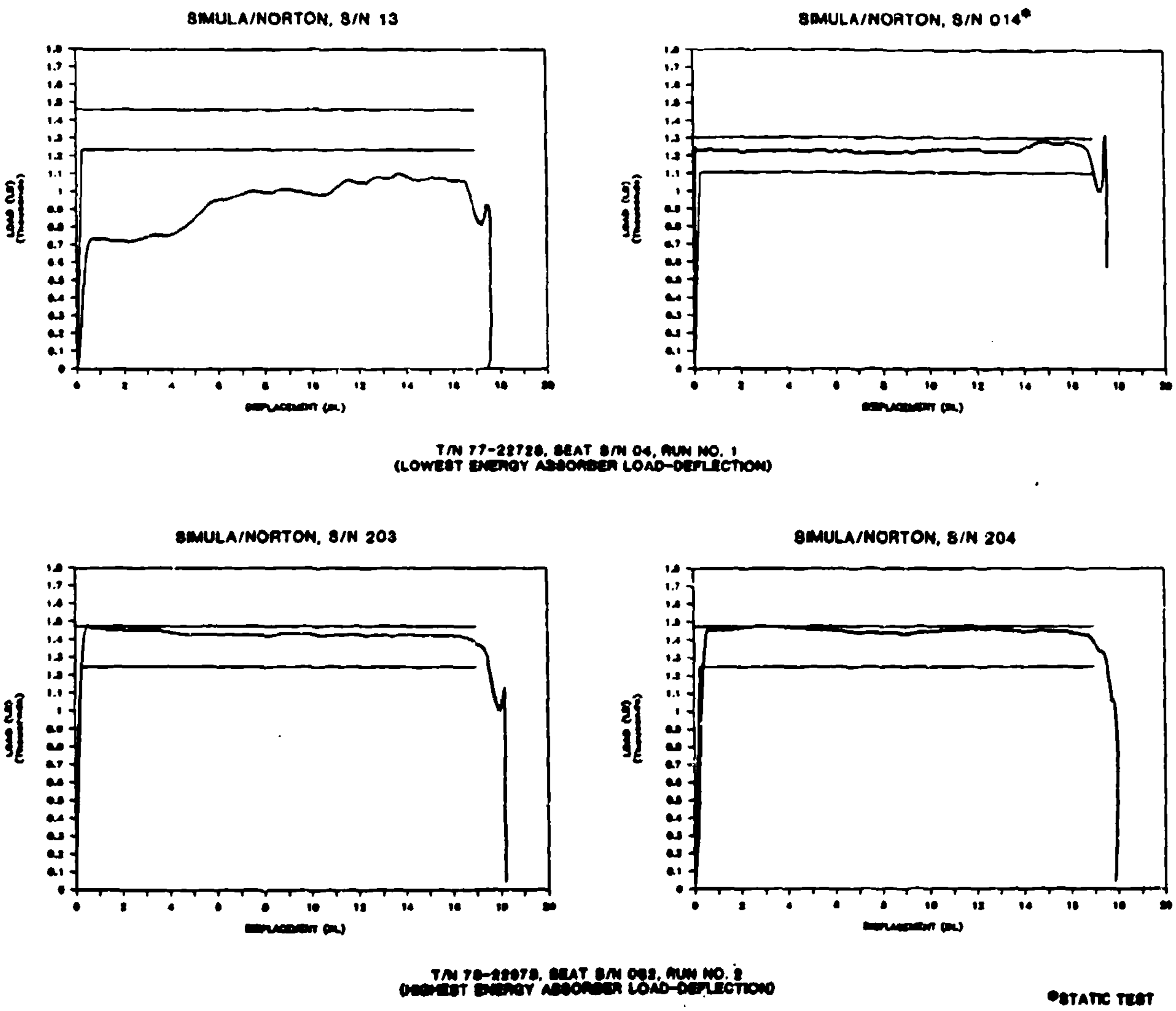


FIGURE 44. SIMULA/NORTON ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS FOR SOM-LA MODELS.

TABLE 19. SIMULA/NORTON SOM-LA MODEL RESULTS

Run No.	Maximum DRI	Maximum Spinal Load (lb)	Vertical Stroke (in.)	Description
1	16.0	1529	16.37	Lowest energy absorber loads
2	19.6	2124	11.02	Highest energy absorber loads
3	18.4	1950	12.65	Nominal energy absorber loads

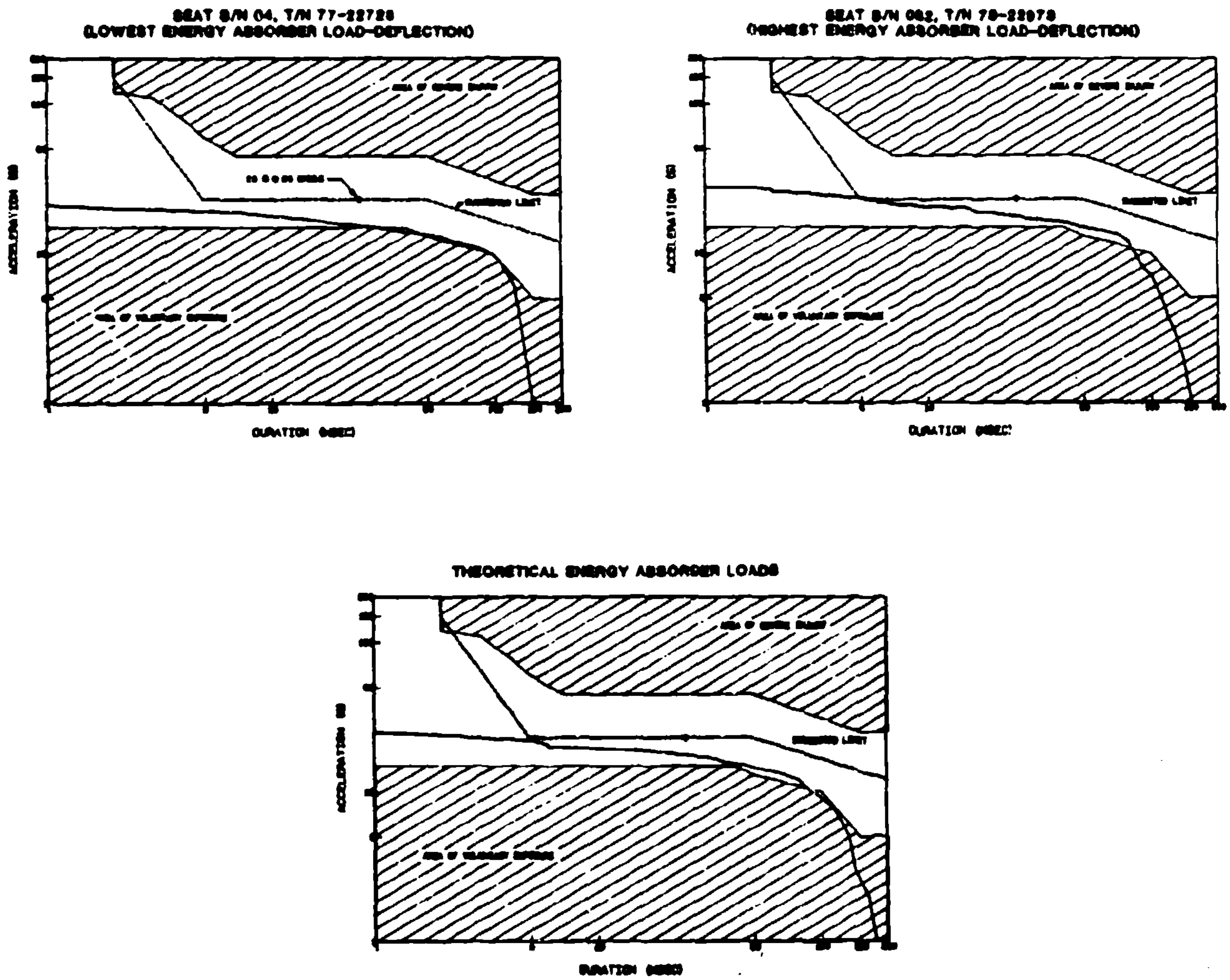


FIGURE 45. EIBAND PLOTS FOR SIMULA/NORTON SOM-LA MODEL PELVIS VERTICAL ACCELERATION.

11.0 CONCLUDING REMARKS

11.1 SIKORSKY TROOP SEAT ENERGY ABSORBERS

Fielded energy absorbers had an overall failure rate of 48 percent. Aircraft with twice the flight hours had approximately twice the failure rate (2261 versus 1200 hours and a 67 percent versus 29 percent failure rate), which suggests that the problem is fatigue related.

During testing, all energy absorbers which failed broke before reaching the nominal stroking load of 1300 lb. This indicates that the strength of the wire was reduced and the failures were not caused by binding of the rollers or some other factor which may have increased the stroking load beyond the tensile limit of the original wire. The incorporation of a load-distributing saddle had no effect on the energy absorber dynamic testing failures.

The energy absorbers that did not fail had load-deflection characteristics similar to those of the new energy absorbers. Both new and fielded energy absorbers typically stroked approximately 280 lb lower than the design nominal stroking load. The lower stroking loads required approximately 2.0 in. more stroke than a nominal load. Whether this lower stroking load is acceptable or not should be verified by actual seat testing. The stroking loads used during the seat qualification testing are unknown. However, verbal information received from Sikorsky Aircraft engineers indicate that the energy absorbers tested at that time stroked at 1300 lb. The lower stroking load may even be desirable since the troop seat occupants typically wear backpacks, which may increase the spinal loads beyond tolerable limits. However, the manner in which the backpack inertial loads are reacted in a crash was not part of this program and should be considered.

11.2 ARA CREW SEAT ENERGY ABSORBERS

The majority of the new and fielded energy absorbers did not meet the manufacturer-specified load-deflection requirements. However, the load-deflection response of fielded energy absorbers was similar to that of the new energy absorbers. Negligible evidence of corrosion was identified on the fielded energy absorbers.

The SOM-LA modeling indicates no increase in the occupant injury level for the fielded energy absorbers as compared to the theoretical nominal energy absorbers with respect to DRI, Eiband tolerance, and spinal loading during a pure vertical crash impact. This is because the -2 energy absorbers--which primarily determine spinal injury--were within or lower than the load limits at the start of stroke. The lower stroking loads could, however, increase the horizontal motion of the seat for combined/forward crash impacts, increasing the possibility of missing the floorwell and bottoming out in the crashes with high vertical components of velocity. It also increases the secondary strike potential for all crashes.

11.3 SIMULA/NORTON CREW SEAT ENERGY ABSORBERS

Both the new and fielded energy absorbers predominately conformed to the manufacturer's specified load-deflection requirements. Although several of the fielded energy absorbers experienced visible corrosion, this did not cause any failures or affect the load-deflection characteristics. One energy absorber was well below the specified stroking load, which would have increased the seat vertical stroking distance by approximately 3.7 in. This could have caused the seat to bottom out depending on the crash energy, seat vertical adjustment, and pilot weight.

12.0 RECOMMENDATIONS

12.1 SIKORSKY TROOP SEAT ENERGY ABSORBERS

The fielded energy absorbers had a high failure rate which appeared to be due to overstress, aggravated by a prolonged vibratory environment. To help prevent failure, the following steps are recommended:

- Replace fielded energy absorbers with new ones starting with the aircraft having the most flight hours
- Dynamically test the replaced energy absorbers to determine their useful life in flight hours
- Redesign the energy absorber to increase their life or continue to replace the energy absorbers when the determined limit is reached.

Both new and fielded energy absorbers were stroking approximately 280 lb below the specified nominal stroking load. Design data should be reviewed to verify the desired stroking load.

12.2 ARA CREW SEAT ENERGY ABSORBERS

Both the new and fielded energy absorbers exhibited load/deflection characteristics that varied quite widely from one to another and from the design specifications. The calculated DRI's and Eiband curves were very high, indicating a high probability of injury. It is recommended that the seat's performance be evaluated in actual crashes to see if injuries are occurring as predicted.

Fielded energy absorbers demonstrated similar load-deflection characteristics when compared to new energy absorbers and environmental effects appeared negligible. However, these energy absorbers were less than seven years old, and the internal packing oil, which appears to be critical for corrosion protection, is seeping out. It is recommended that further testing be performed later to determine if loss of protective oil will cause a problem. To reduce testing costs, only the middle two energy absorbers (-2 part numbers) could be replaced and tested. These energy absorbers are the most critical for occupant protection in a vertical crash.

12.3 SIMULA/NORTON CREW SEAT ENERGY ABSORBERS

These energy absorbers demonstrated proper load-deflection characteristics but also showed signs of corrosion. To help prevent performance degradation, the following steps are recommended:

- Continue monitoring energy absorber corrosion for the oldest aircraft and those subjected to the worst environment to determine useful life expectancy
- Investigate methods of improved sealing of the energy absorber end caps for new and replacement units.

13.0 REFERENCES

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2. Laananen, D. H., Bolukbasi, A. O., and Coltman, J. W., Computer Simulation of an Aircraft Seat and Occupant in a Crash Environment, Volume I, Technical Report, Simula Inc,. Report No. DOT/FAA/CT-82/33-1, U.S. Department of Transportation, Federal Aviation Administration, Washington D.C., 1983.

3. Laananen, D. H., Aircraft Crash Survival Design Guide, Volume II - Aircraft Crash Environment and Human Tolerance, Simula Inc., USARTL-TR-79-22B, Applied Technology Laboratory, U.S. Army Research and Technology Laboratories (AVRADCOM), Fort Eustis, Virginia, January 1980, AD-A082512.

4. Eiband, A. M., Human Tolerance to Rapidly Applied Accelerations: A Summary of the Literature, NASA Memorandum 5-19-59E, National Aeronautics and Space Administration, Washington, DC, June 1959.

5. Military Specification, MIL-S-58095A(AV), General Specification for Crash-Resistant, Non-Ejection, Aircrew Seat System, Department of Defense, Washington, DC, January 1986.

APPENDIX A
AIRCRAFT DATA SHEETS AND ENERGY ABSORBER INSPECTED LENGTHS

TABLE A-1. SIMULA/NORTON ENERGY ABSORBER LENGTH SHEET

Aircraft		Pilot		Copilot	
Tail Number		Left	Right	Left	Right
77-22728	S/N	14	13	47	46
	Length (in.)	12.210	12.168	12.202	12.204
77-22966	S/N	142	143	1516	0188
	Length (in.)	12.188	12.195	12.161	12.188
78-22973	S/N	224	225	203	204
	Length (in.)	12.184	12.193	12.181	12.204
78-22990	S/N	296	297	282	283
	Length (in.)	12.193	12.175	12.205	12.204
78-22991	S/N	286	287	167	168
	Length (in.)	12.218	12.200	12.189	12.181

Desired Length: 12.187 in.

TABLE A-2. ARA ENERGY ABSORBER LENGTH SHEET

Aircraft		Pilot		Copilot	
Tail Number		Left	Right	Left	Right
81-23597	-1	6.30	6.29	6.31	6.275
	-2	8.81	8.82	8.81	8.815
	-3	9.38	9.40	9.39	9.39
81-23598	-1	6.295	6.28	6.30	6.27
	-2	8.79	8.81	8.81	8.83
	-3	9.39	9.407	9.40	9.40
81-23601	-1	6.30	6.27	6.29	6.275
	-2	8.81	8.82	8.80	8.80
	-3	9.39	9.38	9.40	9.40
81-23619	-1	6.28	6.28	6.295	6.28
	-2	8.80	8.82	8.79	8.79
	-3	9.39	9.40	9.385	9.41
82-23678	-1	6.28	6.29	6.28	6.28
	-2	8.805	8.80	8.81	8.79
	-3	9.39	9.40	9.39	9.395

TROOP SEAT ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 77-22720

DATE OF MANUFACTURE 5-79

NUMBER OF FLIGHT HOURS 2,261

HOME BASE Ft. Rucker, AL

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

STATION HISTORY

PAST STATIONS LENGTH OF STAY

Accepted @ Ft. Rucker: 5-79
Ft. Rucker: 5-79 to 6-83
Sikorsky Bridgeport: 11-83 to 3-84
Ft. Campbell, KY
(A Co., 101st Abn. Div.):
3-84 to 6-86
Ft. Rucker (6th Btn, 159th Avn. Rgmt.): 6-86 to present.
(10 Aug 88)

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

- All troop seat restraints were noted to have been replaced 29 July 1983. No other action noted pertaining to Troop/Gunner seats.
- No evidence found of any hard landings.

INTERIOR CONDITION OF AIRCRAFT

This aircraft had 2 side-facing gunner seats and 11 additional troop seats: 4 forward facing along aft bulkhead, 4 rear facing at midship, and 3 forward facing at midship. All energy absorbers were replaced except left side gunner seat.

TROOP SEAT ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 78-22971

DATE OF MANUFACTURE 10-79

NUMBER OF FLIGHT HOURS 1,200

HOME BASE Ft. Eustis, VA

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Aircraft has been used for routine troop haul and cargo missions plus flight crew training.

STATION HISTORY

PAST STATIONS LENGTH OF STAY

Accepted @ Ft. Eustis: 10-79
Aircraft has been assigned to the Aviation Office, Ft. Eustis for its entire history.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

No evidence found of any hard landings.

INTERIOR CONDITION OF AIRCRAFT

Average to good for aircraft of this age.

ARA ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 81-23598

DATE OF MANUFACTURE 7-82

NUMBER OF FLIGHT HOURS 997.9

HOME BASE Wiesbaden

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

None noted.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

None.

INTERIOR CONDITION OF AIRCRAFT

Clean, nothing remarkable

STATION HISTORY

PAST STATIONS	LENGTH OF STAY
Wiesbaden:	1-82 to 2-83
Nellingen:	2-83 to 5-86
Wiesbaden:	5-86 to 12-87
Hanau:	12-87 to 3-88
Wiesbaden:	3-88 to present

2	ARA ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 81-23598

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT | Jun 82 043

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Good many coats of paint. Looks like they spray the whole seat.
Usual wear on edges.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Clean - see above.

ENERGY ABSORBER CONDITION

ENVIRONMENT
Many coats of paint

INSTALLATION
Nothing remarkable

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		TOP	MIDDLE	BOTTOM
	RH	0140	0114	094
	LH	0101	0109	083

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT | June 82 042

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

See above

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

See above

ENERGY ABSORBER CONDITION

ENVIRONMENT
See above

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		TOP	MIDDLE	BOTTOM
	RH	120	088	092
	LH	017	0107	01

ARA ENERGY ABSORBER
OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 81-23597

DATE OF MANUFACTURE 7-82

NUMBER OF FLIGHT HOURS 873.2

HOME BASE Grafenwohr

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Used in tactical combat unit for training.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

Nothing remarkable.

INTERIOR CONDITION OF AIRCRAFT

Clean, nothing remarkable.

STATION HISTORY

PAST STATIONS	LENGTH OF STAY
Wiesbaden:	7-82 to 1-87
Grafenwohr:	1-87 to present

2	ARA ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 81-23597

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT | 031 |

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Usual signs of wear, velcro coming off spall shield.
Dirt and grime.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Has not been painted.

ENERGY ABSORBER CONDITION

ENVIRONMENT

nothing remarkable

INSTALLATION

A bear

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT			
RH	0103	0106	0106
LH	095	091	0101
	TOP	MIDDLE	BOTTOM

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT | Missing placard |

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

See above

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

See above

ENERGY ABSORBER CONDITION

ENVIRONMENT

INSTALLATION

See above

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT			
RH	0114	086	0114
LH	099	097	095
	TOP	MIDDLE	BOTTOM

ARA ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 81-23601

DATE OF MANUFACTURE 7-82

NUMBER OF FLIGHT HOURS 1,031.8

HOME BASE Ft. Campbell, KY

STATION HISTORY

PAST STATIONS	LENGTH OF STAY

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Delivered to Ft. Campbell, KY, July 82.
Two weeks at Troy, AL (Aug 87) for instal. of flt. data recorder.

Otherwise - always @ Ft. Campbell, KY.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

Variety of troop/equipment transport missions.
No evidence of hard landings.

INTERIOR CONDITION OF AIRCRAFT

Light/moderate, dust/dirt.

2 ARA ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 81-23601

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT 046

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

No unusual wear, corrosion.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Moderate dust/dirt.

ENERGY ABSORBER CONDITION

ENVIRONMENT

Dust/dirt.

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		TOP	MIDDLE	BOTTOM
	RH	0137	0102	079
	LH	0118	072	0103

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT 045

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

No unusual wear, corrosion.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Moderate dust/dirt

ENERGY ABSORBER CONDITION

ENVIRONMENT

Dust/dirt/

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		TOP	MIDDLE	BOTTOM
	RH	0142	0112	098
	LH	0145	0101	089

ARA ENERGY ABSORBER
OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 81-23619

DATE OF MANUFACTURE 9-82

NUMBER OF FLIGHT HOURS 1,303.8

HOME BASE Ft. Benning - delivered 9-20-82

STATION HISTORY

PAST STATIONS	LENGTH OF STAY

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Stayed at Ft. Benning.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

Nothing remarkable.

INTERIOR CONDITION OF AIRCRAFT

Nothing remarkable.
Somewhat dirty.

2 ARA ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 81-23619

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT — S/N 081 Mnf. 9/82

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Wear on edges of spall shield.
Cushions worn out.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Dust, grime.

ENERGY ABSORBER CONDITION

ENVIRONMENT

Dirt, dust

INSTALLATION

Nothing remarkable

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT	TOP	MIDDLE	BOTTOM
RH	0208	0163	0172
LH	0215	0158	0174

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT — S/N 077 Mnf. 9/82

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Chafing all around edge of seat.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Dust, grime.

ENERGY ABSORBER CONDITION

ENVIRONMENT

Dirt, dust.

INSTALLATION

Nothing remarkable.

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT	TOP	MIDDLE	BOTTOM
RH	0216	0196	0168
LH	0209	0188	0179

ARA ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 82-23678

DATE OF MANUFACTURE 11-82

NUMBER OF FLIGHT HOURS 1,128.8

HOME BASE Gray AAF, Ft. Lewis, WA

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Aircraft delivered new to B Co. 219th Avn. Rgmt. - Ft. Lewis, WA (Jan. 83).

Aircraft used for routine training troop & cargo hauling missions.

STATION HISTORY

PAST STATIONS	LENGTH OF STAY

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

No evidence of hard landings or unusual abuse.

INTERIOR CONDITION OF AIRCRAFT

Light dust - normal wear for an aircraft of this age.

2 ARA ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 82-23678

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT S/N 0126

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Dusty, light corrosion on height adjust guide tubes.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Very light dust.

ENERGY ABSORBER CONDITION

ENVIRONMENT

Dusty

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		TOP	MIDDLE	BOTTOM
	RH	0310	0259	0278
	LH	0311	0262	0279

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT S/N 0128

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Dusty, light corrosion on height adjust guide tubes.
Seat hard to raise & lower.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Very light dust

ENERGY ABSORBER CONDITION

ENVIRONMENT

Dusty

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		TOP	MIDDLE	BOTTOM
	RH	0316	0265	0280
	LH	0321	0268	0281

N/S ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 77-22728

DATE OF MANUFACTURE 7-79

NUMBER OF FLIGHT HOURS 1,535.4

HOME BASE Ft. Benning

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

See station history.

STATION HISTORY

PAST STATIONS LENGTH OF STAY

Ft. Campbell: 7-79 to 4-85
158th Av. Batt. & 101st/160 Taskforce

Sikorsky: 4-85 to 12-86

Ft. Benning: 12-86 to present

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

Nothing remarkable.

INTERIOR CONDITION OF AIRCRAFT

Very clean considering its age.

2 N/S ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO 77-22728

SEAT TYPE AND SERIAL NUMBER. PILOT COPILOT S/N 00004

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

ENERGY ABSORBER CONDITION

ENVIRONMENT	INSTALLATION
Dirty on top Has been painted	Intercom cable attached to R.H. energy absorber

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT
RH 00013
LH 00014

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT S/N 00012

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)
Little wear, probably painted since placard has
been pained.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

ENERGY ABSORBER CONDITION

ENVIRONMENT	INSTALLATION
Clean, nothing remarkable	Intercom cable attached to R.H. energy absorber

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT
RH 00046
LH 00047

N/S ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 78-22973

DATE OF MANUFACTURE 12-79

NUMBER OF FLIGHT HOURS 1,764

HOME BASE Ft. Campbell, KY

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Normal Troop/Equipment transport.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

No evidence of hard landings.

INTERIOR CONDITION OF AIRCRAFT

Light/Moderate, Dust/Dirt

STATION HISTORY

PAST STATIONS	LENGTH OF STAY
Delivered 30 Oct 79 to and always based @ Ft. Campbell	

2 N/S ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO 78-22973

SEAT TYPE AND SERIAL NUMBER PILOT COPILOT 00089 (Frame) 00083 (Bucket)

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Moderate pitting both guide tubes
Both rubber pads on bucket diagonals missing
Suspect frame to have been changed due to S/N mismatch

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Moderate dirt/dust

ENERGY ABSORBER CONDITION

ENVIRONMENT
Light dust

INSTALLATION
No evidence of damage

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT
RH 00225
LH 00224

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT 00082 (Frame) No bucket data plate

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Moderate pitting outboard (L) guide tube
Light pitting inboard guide tube

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Moderate dirt/dust
Wear on spall shielding edges

ENERGY ABSORBER CONDITION

ENVIRONMENT
Light dust

INSTALLATION
No evidence of damage

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT
RH 00204
LH 00203

N/S ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 78-22990

DATE OF MANUFACTURE 12-79

NUMBER OF FLIGHT HOURS 1,671.5

HOME BASE Darmstadt

STATION HISTORY

PAST STATIONS LENGTH OF STAY

Sikorsky: 6-80 to 12-82
Ft. Campbell: 12-82 to 3-84
Went to Grenada

Sikorsky: 7-84 to 10-85
Darmstadt: 10-85 to present

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

See station history.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

Nothing remarkable.
Went to Sikorsky for rework after Grenada.

INTERIOR CONDITION OF AIRCRAFT

Clean, nothing remarkable.

2 N/S ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 78-22990

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT 00118

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Corrosion on guide tubes, general wear.
Horizontal movement is smooth.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Looks like seat has been painted at least once.

ENERGY ABSORBER CONDITION

ENVIRONMENT

INSTALLATION

Radio cable attached to R.H. energy absorber

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT

RH 00297

LH 00296

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT Missing placard

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

See above

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

ENERGY ABSORBER CONDITION

ENVIRONMENT

INSTALLATION

Radio cable attached to R.H. energy absorber

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT

RH 00283

LH 00282

N/S ENERGY ABSORBER
OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 78-22991

STATION HISTORY

PAST STATIONS	LENGTH OF STAY

DATE OF MANUFACTURE 1-80

NUMBER OF FLIGHT HOURS 1,723

HOME BASE Nellingen, FRG

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

NOTE: This aircraft formally assigned to 160th Task Force at Ft. Campbell, KY, and due to sensitive nature of missions, no records of this activity are available.

March 1980 - aircraft delivered to Ft. Campbell, KY - 101st Abn. Div. (158th Avn. Bn.) [This is really the 160th]

October 1986 - Aircraft delivered to 45th Med. Co. - Nellingen.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

Aircraft was rebuilt by Sikorsky (Troy, AL) beginning 1-86.

INTERIOR CONDITION OF AIRCRAFT

Light dirt/dust, but generally good.

2 N/S ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 78-22991

45th Medical Co., 421st Evac. Btn.; Nellingen, FRG

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT S/N 0120

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Minor pitting on guide tubes, seat cushion worn. Dusty (light)
New 1986 (5000#) inertia reel
Inertia reel strap w/ edge fraying (mfg. 6081); Rubber pad missing on top left bucket diagonal

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Generally good - no excessive dirt

ENERGY ABSORBER CONDITION

ENVIRONMENT INSTALLATION

Generally good - no excessive dirt, oil etc.

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT
RH 00287
LH 00286

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT S/N 0064

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Good - no evidence of corrosion, cushions ok.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Generally good - as above.

ENERGY ABSORBER CONDITION

ENVIRONMENT INSTALLATION

Generally good - as above.

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT
RH 00168
LH 00167

N/S ENERGY ABSORBER OPERATIONAL DATA SHEET

AIRCRAFT INFORMATION

AIRCRAFT TAIL NO. 78-22966

STATION HISTORY

PAST STATIONS LENGTH OF STAY

DATE OF MANUFACTURE 8-79

NUMBER OF FLIGHT HOURS 1,505

HOME BASE 1st Special Forces Group (Perm. Assigned to C Co. 219 Avn. Rgmt.)
Ft. Lewis

MISSION HISTORY (NOTE ANY EXTREME ENVIRONMENTAL CONDITIONS)

Aircraft delivered (Nov. 79) to D Co. 158th Avn. Btn.; Ft. Campbell.
Aircraft assigned to 160th Task Force @ Ft. Campbell (Aug 82 - Dec. 85)
Bird rebuilt by Sikorsky; Troy, AL (Jan. 86 - Feb. 87). Arrived Ft. Lewis May 87 -219 Avn. Rgmt.
Assigned 1st Special Forces Group, Ft. Lewis Jan. 88.

No specifics on mission history, mostly due to classified nature of missions flown.

MAINTENANCE HISTORY (NOTE ANY HARD LANDINGS)

No evidence of hard landings.

INTERIOR CONDITION OF AIRCRAFT

Exceptionally clean & very well-maintained.

2 N/S ENERGY ABSORBER OPERATIONAL DATA SHEET	AIRCRAFT TAIL NO. 78-22966

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT 00035 (Torn) Frame

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.) Data plate on Bucket is missing

Good/excellent for this age aircraft.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Unusually clean - absence of dirt/dust.

ENERGY ABSORBER CONDITION

ENVIRONMENT

Clean

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		
	RH	00143
	LH	00142

SEAT TYPE AND SERIAL NUMBER: PILOT COPILOT 00066 (Bucket) 00074 (Frame)

SEAT CONDITION (GENERAL WEAR, CORROSION, FOD, ETC.)

Good/excellent for this age aircraft.

SEAT ENVIRONMENT (OBJECTS ATTACHED, PAINT, OIL, ETC.)

Unusually clean - absence of dirt/dust.

ENERGY ABSORBER CONDITION

ENVIRONMENT

Clean

INSTALLATION

ENERGY ABSORBER IDENTIFICATION (ASSIGN NUMBER TO EACH E/A)

SIDE OF SEAT		
	RH	0188
	LH	1516

APPENDIX B

TROOP SEAT ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS

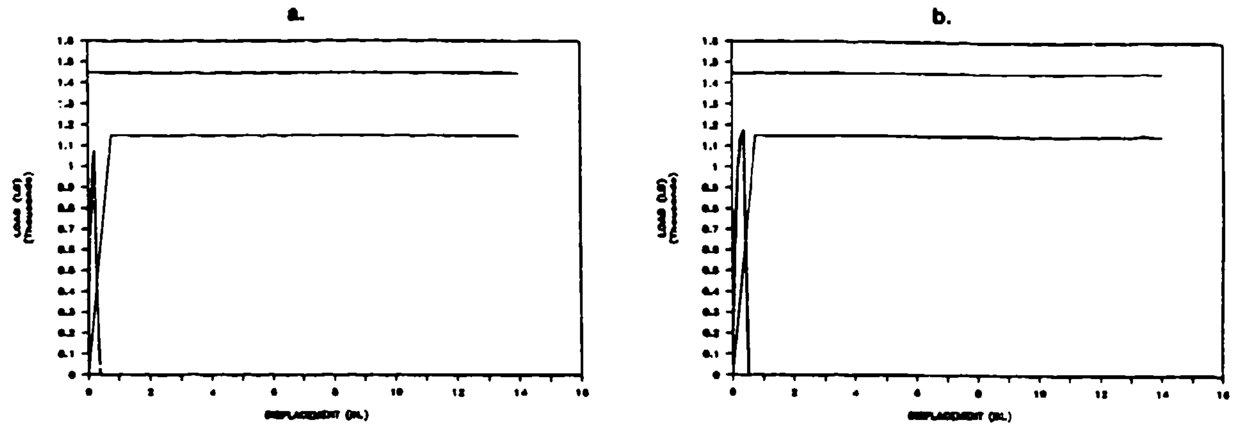

FIGURE B-1. SIKORSKY TROOP SEAT NO. 1, AIRCRAFT T/N 77-22720.

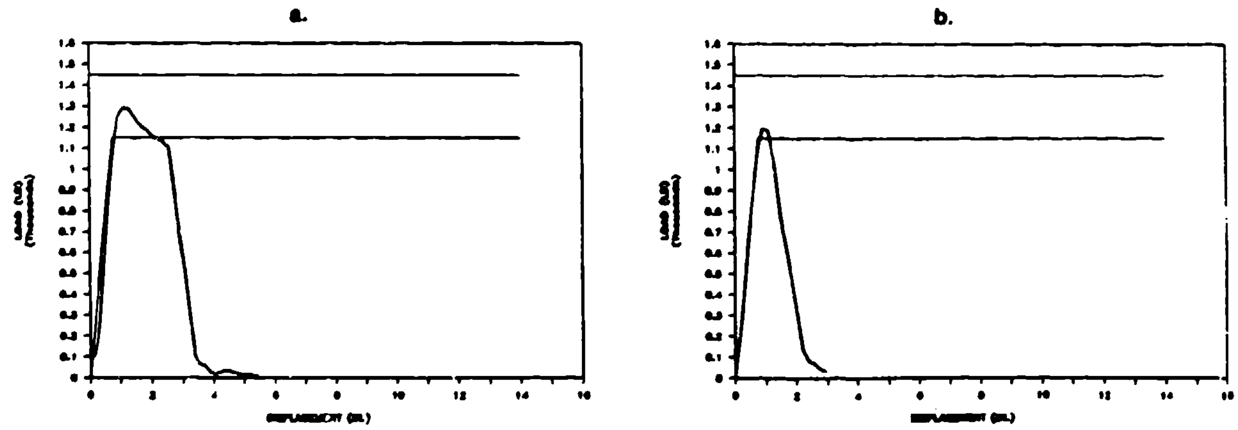

FIGURE B-2. SIKORSKY TROOP SEAT NO. 2, AIRCRAFT T/N 77-22720.

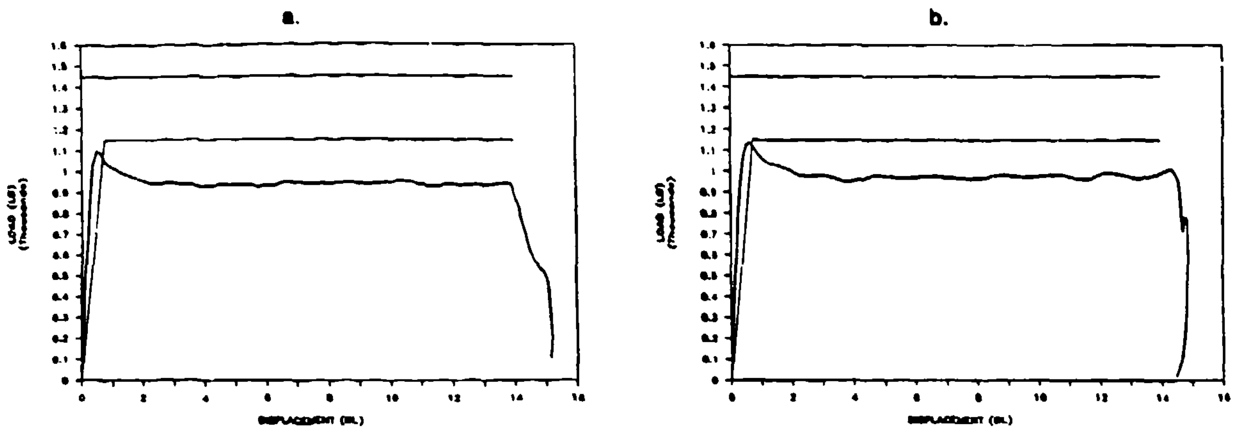

FIGURE B-3. SIKORSKY TROOP SEAT NO. 3, AIRCRAFT T/N 77-22720.

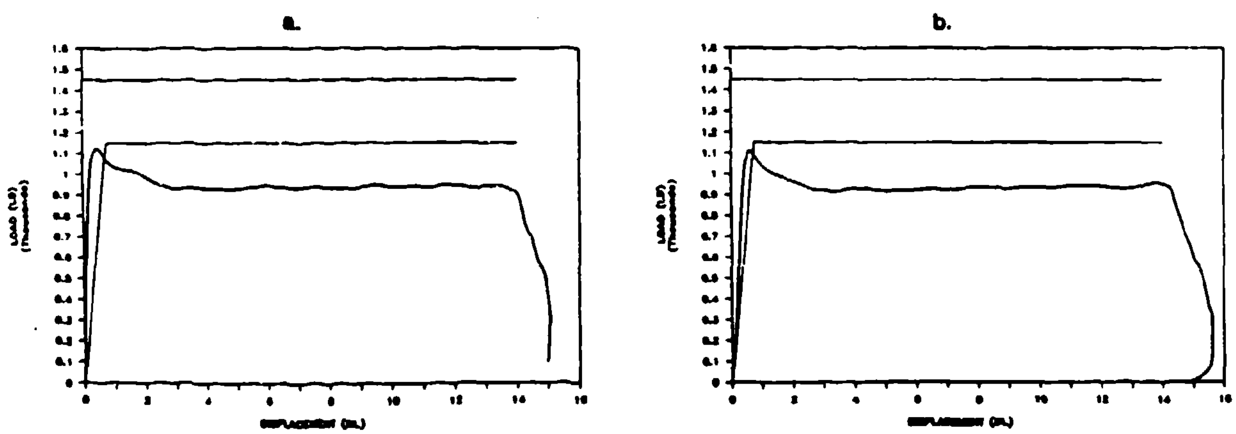

FIGURE B-4. SIKORSKY TROOP SEAT NO. 4, AIRCRAFT T/N 77-22720.

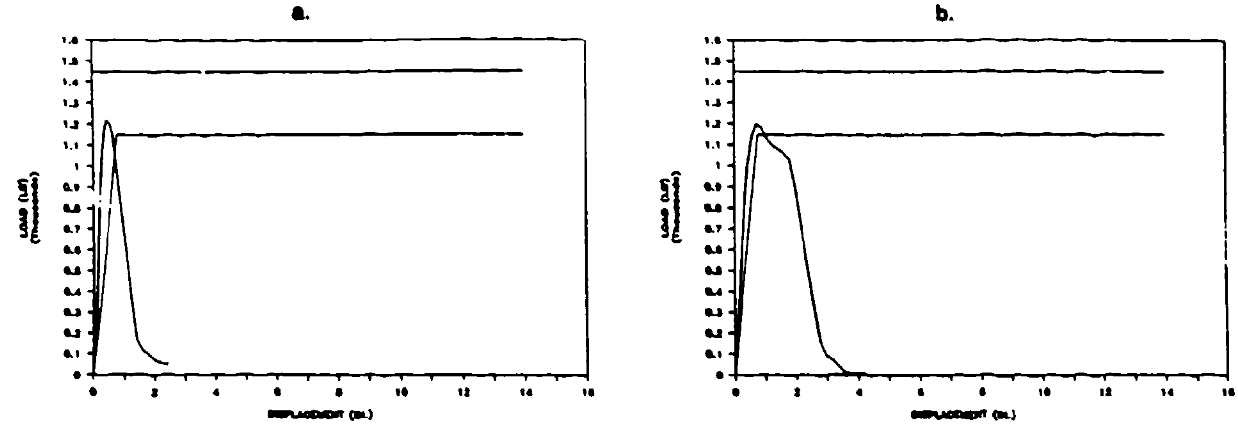

FIGURE B-5. SIKORSKY TROOP SEAT NO. 5, AIRCRAFT T/N 77-22720.

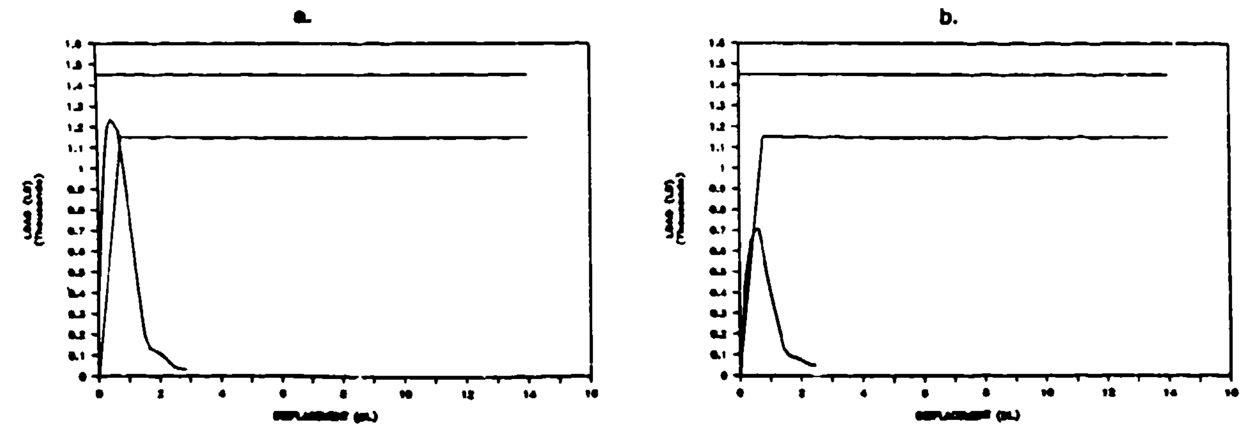

FIGURE B-6. SIKORSKY TROOP SEAT NO. 6, AIRCRAFT T/N 77-22720.

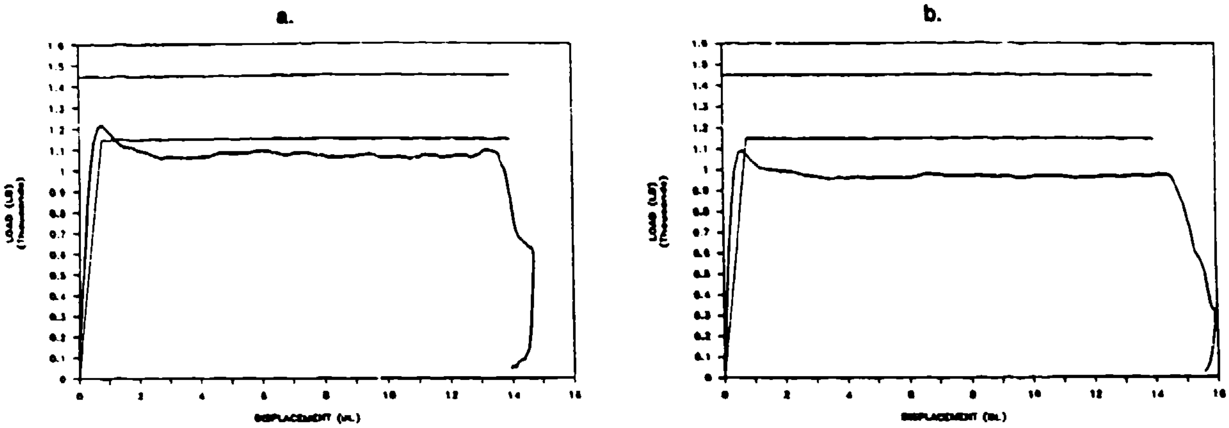

FIGURE B-7. SIKORSKY TROOP SEAT NO. 7, AIRCRAFT T/N 77-22720.

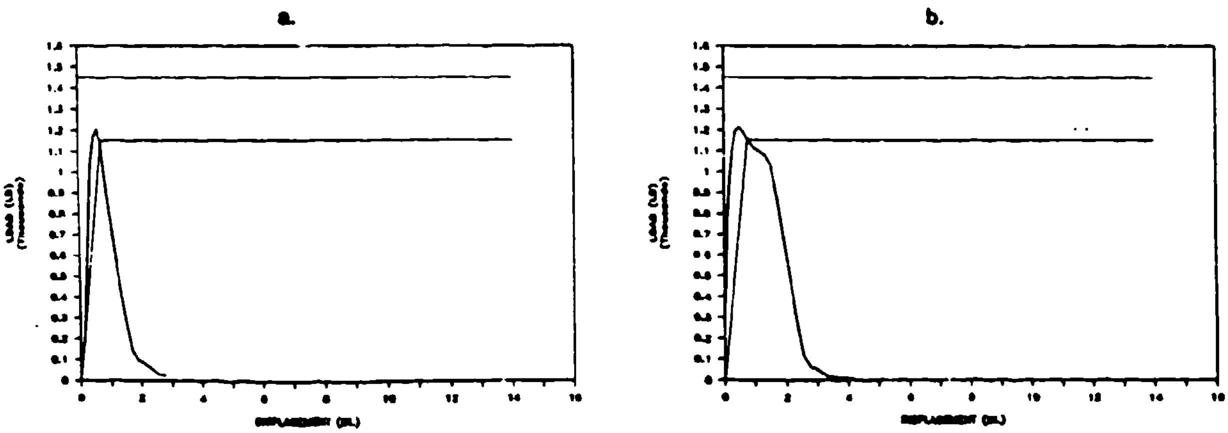

FIGURE B-8. SIKORSKY TROOP SEAT NO. 8, AIRCRAFT T/N 77-22720.

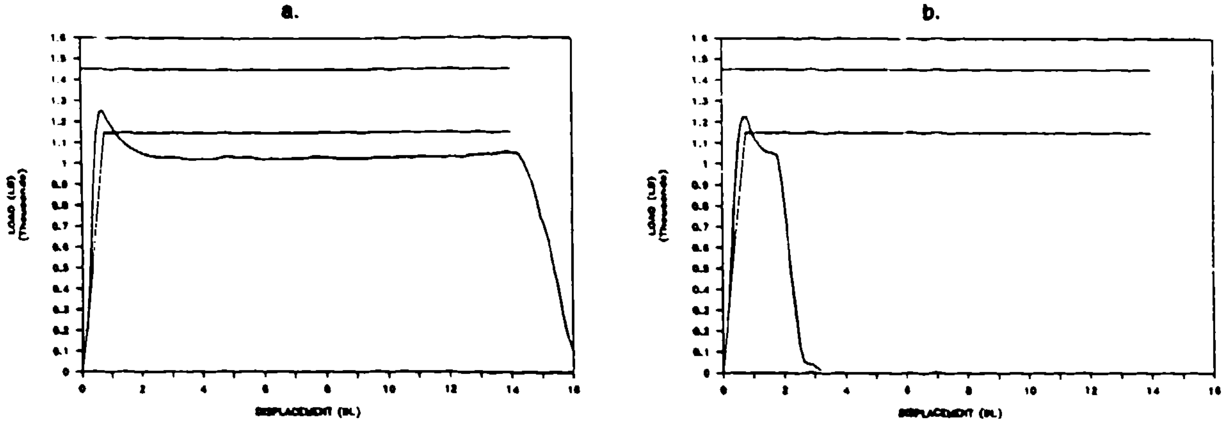

FIGURE B-9. SIKORSKY TROOP SEAT NO. 9, AIRCRAFT T/N 77-22720.

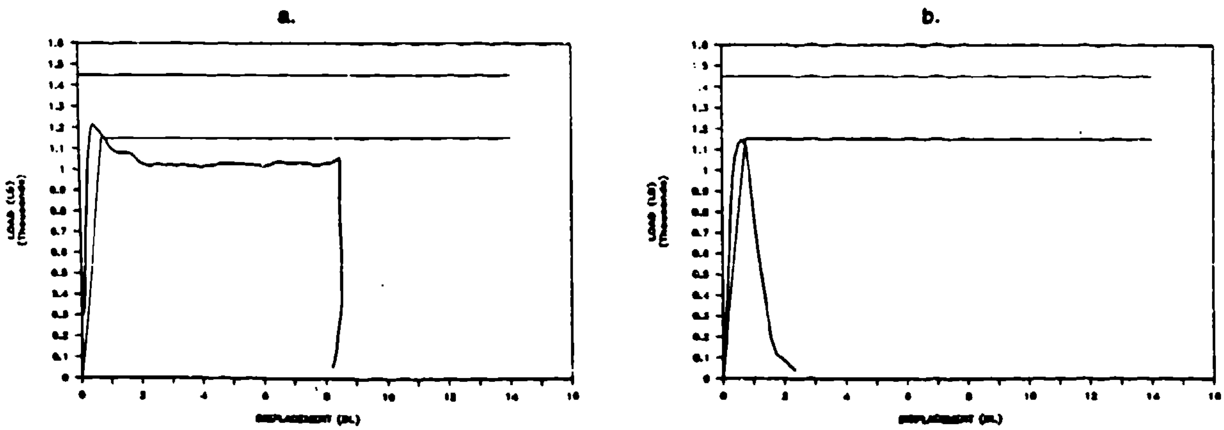

FIGURE B-10. SIKORSKY TROOP SEAT NO. 10, AIRCRAFT T/N 77-22720.

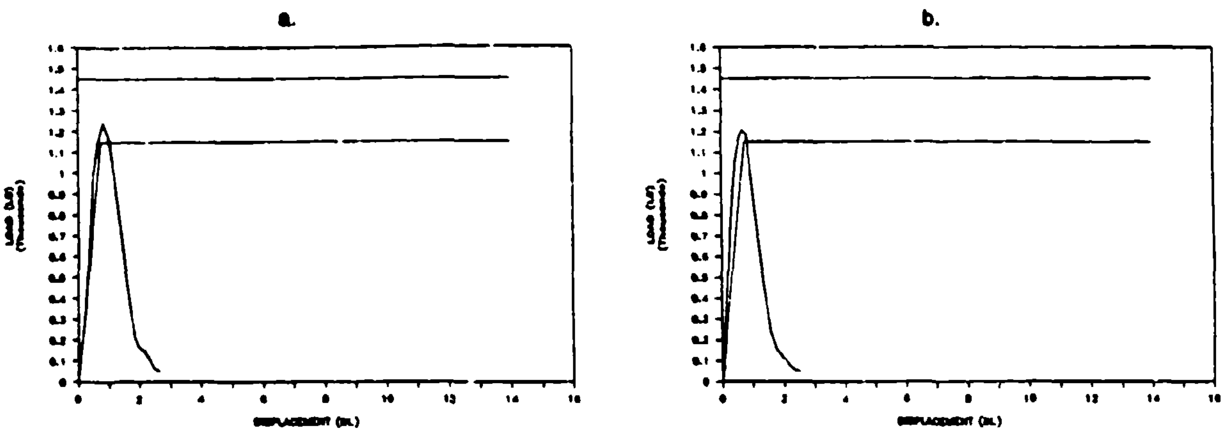

FIGURE B-11. SIKORSKY TROOP SEAT NO. 11, AIRCRAFT T/N 77-22720.

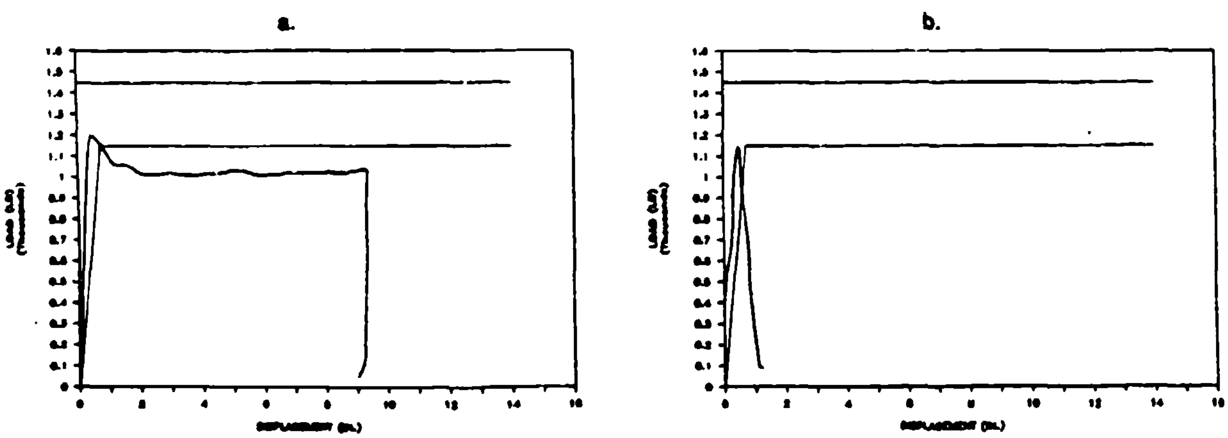

FIGURE B-12. SIKORSKY TROOP SEAT NO. 12, AIRCRAFT T/N 77-22720.

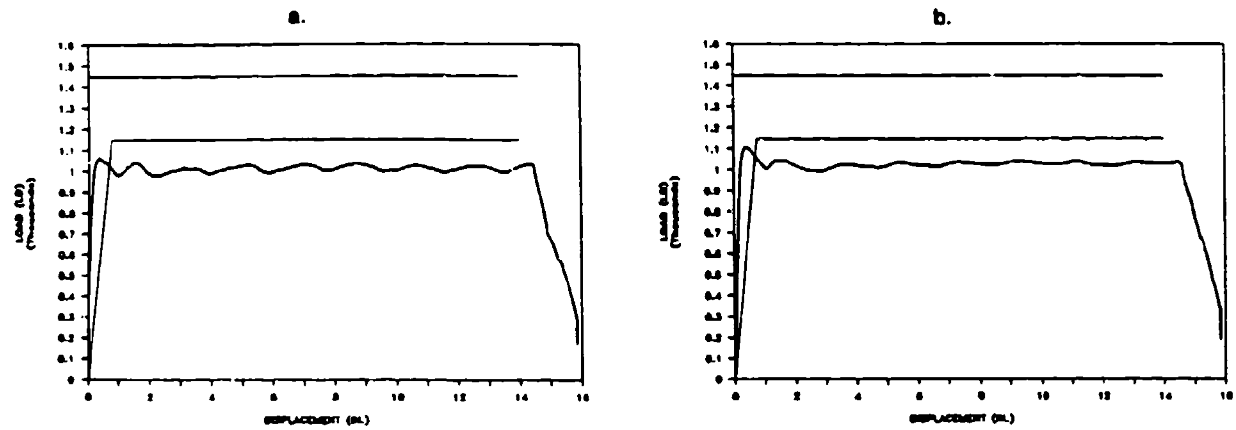

FIGURE B-13. SIKORSKY TROOP SEAT NO. 1, AIRCRAFT T/N 77-22971.

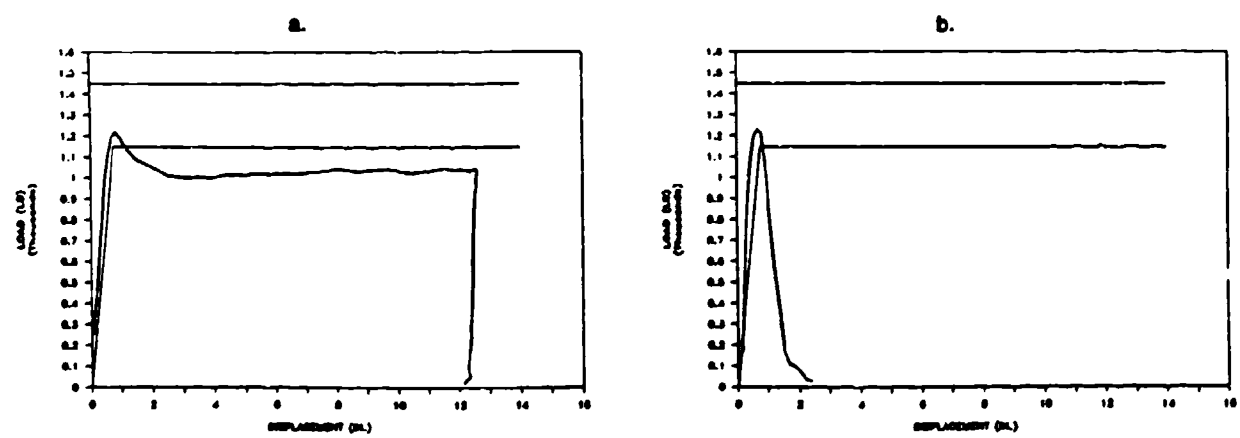

FIGURE B-14. SIKORSKY TROOP SEAT NO. 2, AIRCRAFT T/N 77-22971.

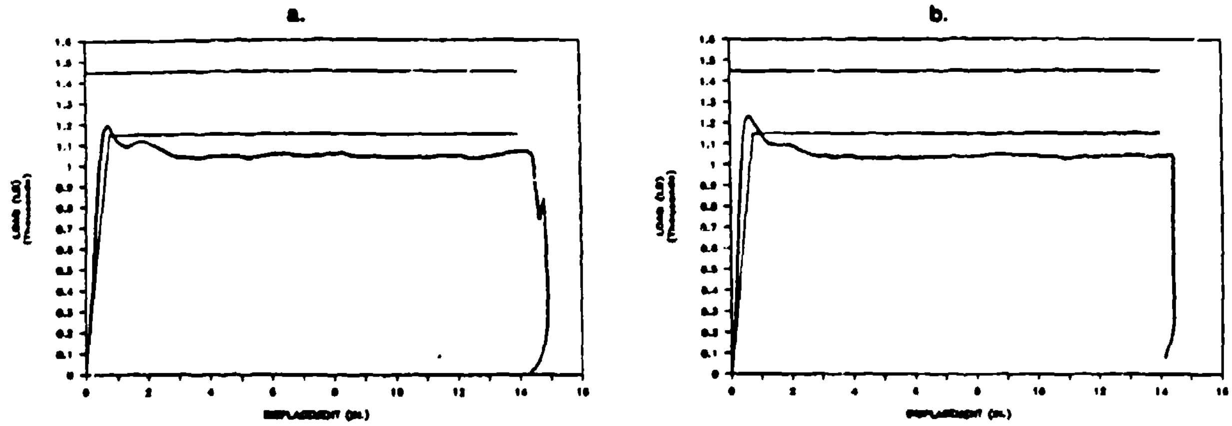

FIGURE B-15. SIKORSKY TROOP SEAT NO. 3, AIRCRAFT T/N 77-22971.

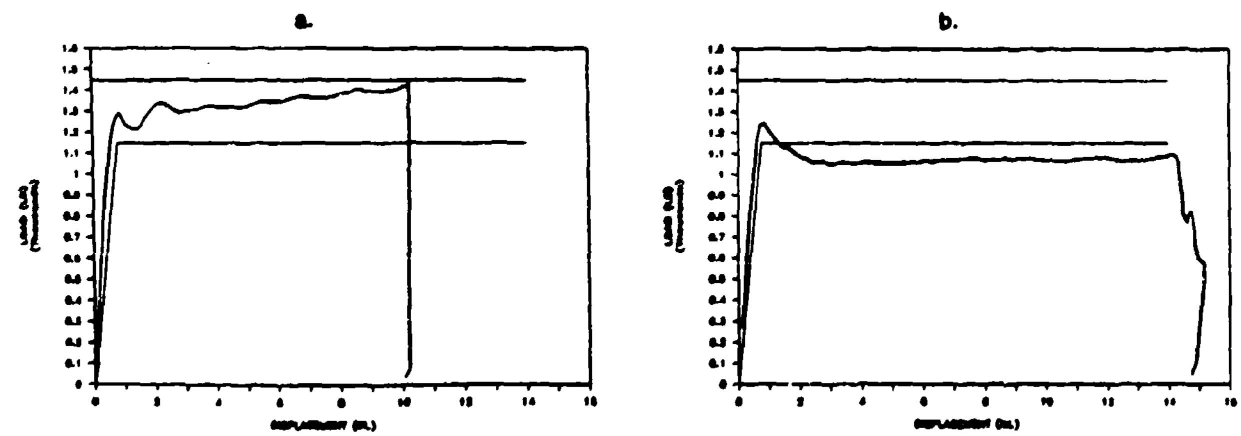

FIGURE B-16. SIKORSKY TROOP SEAT NO. 4, AIRCRAFT T/N 77-22971.

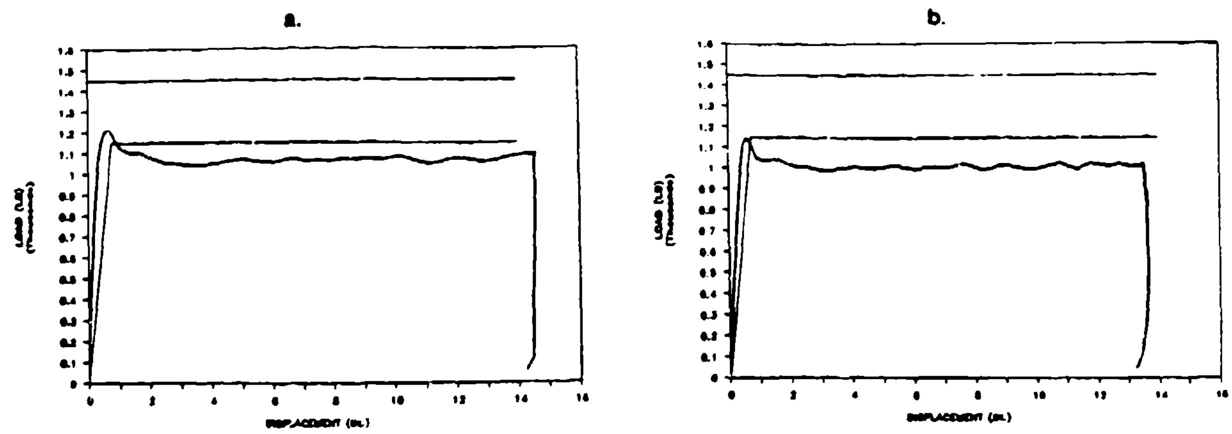

FIGURE B-17. SIKORSKY TROOP SEAT NO. 5, AIRCRAFT T/N 77-22971.

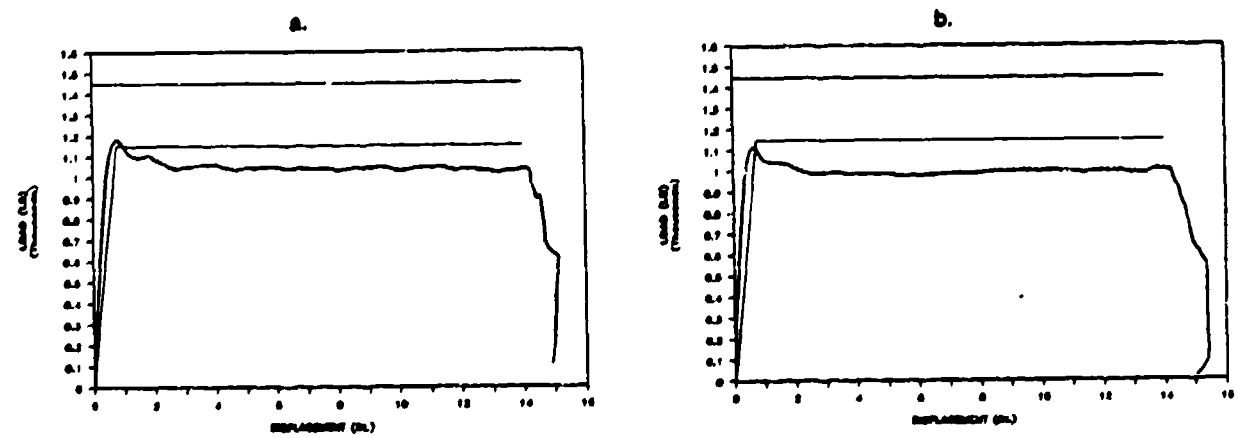

FIGURE B-18. SIKORSKY TROOP SEAT NO. 6, AIRCRAFT T/N 77-22971.

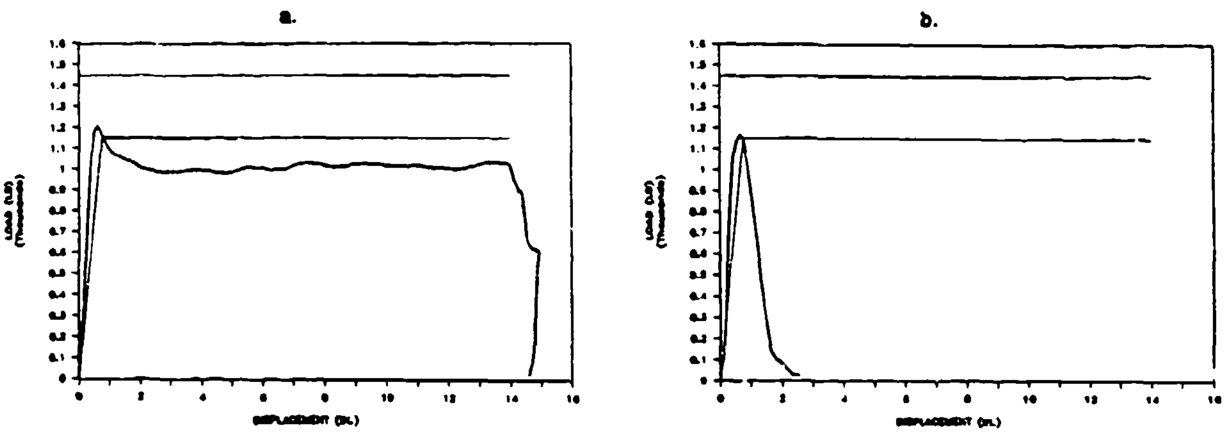

FIGURE B-19. SIKORSKY TROOP SEAT NO. 7, AIRCRAFT T/N 77-22971.

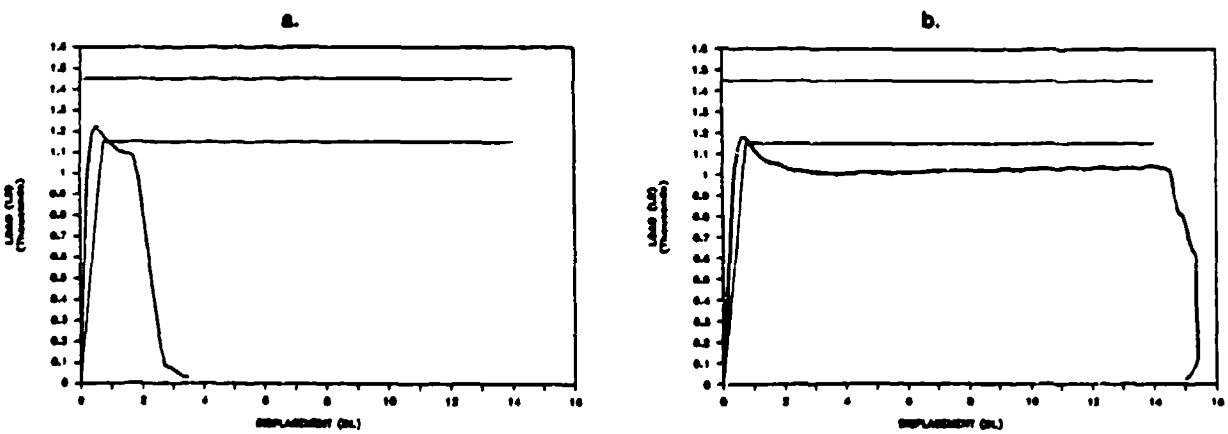

FIGURE B-20. SIKORSKY TROOP SEAT NO. 8, AIRCRAFT T/N 77-22971.

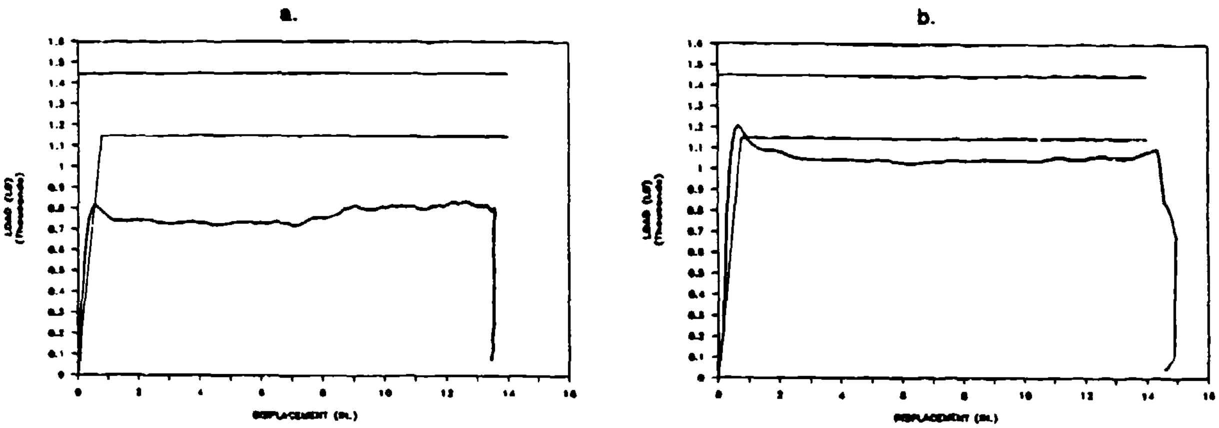

FIGURE B-21. SIKORSKY TROOP SEAT NO. 9, AIRCRAFT T/N 77-22971.

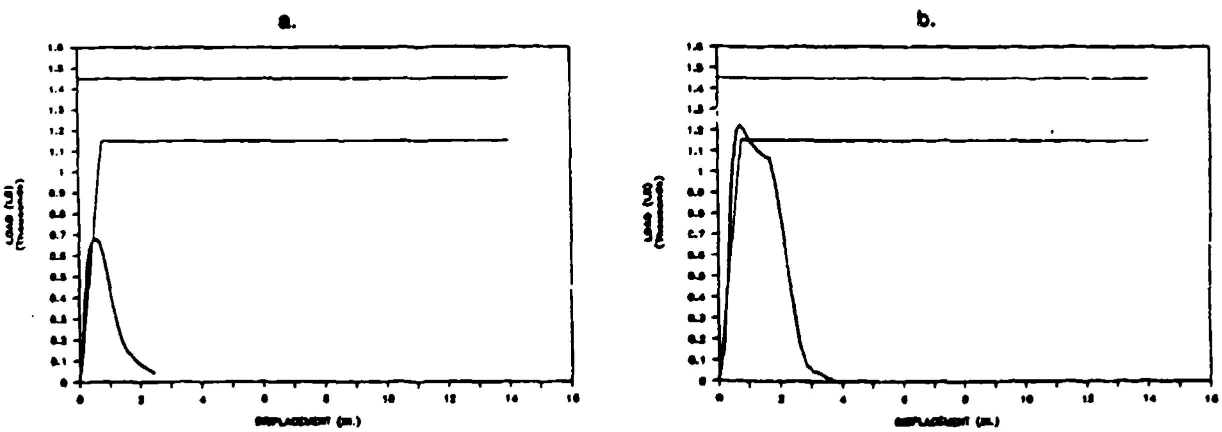

FIGURE B-22. SIKORSKY TROOP SEAT NO. 10, AIRCRAFT T/N 77-22971.

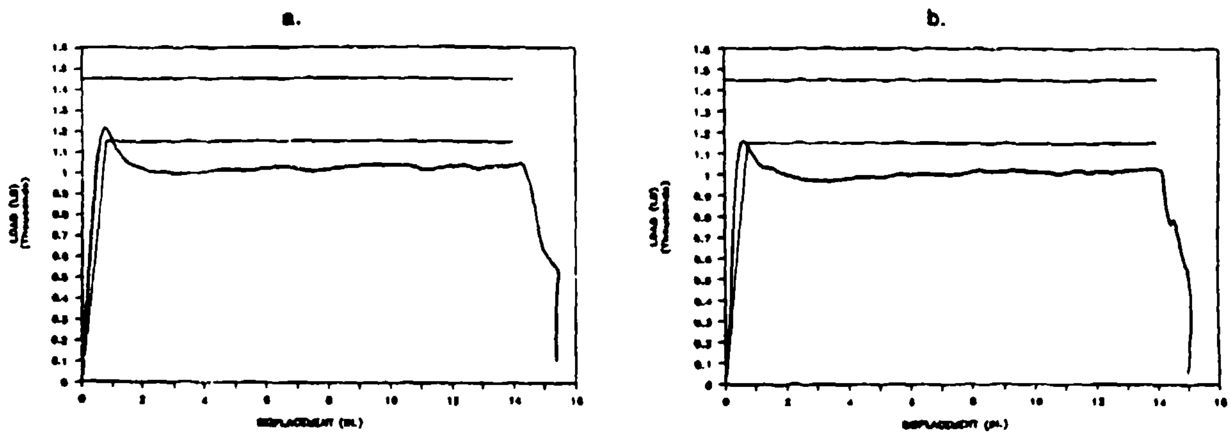

FIGURE B-23. SIKORSKY TROOP SEAT NO. 11, AIRCRAFT T/N 77-22971.

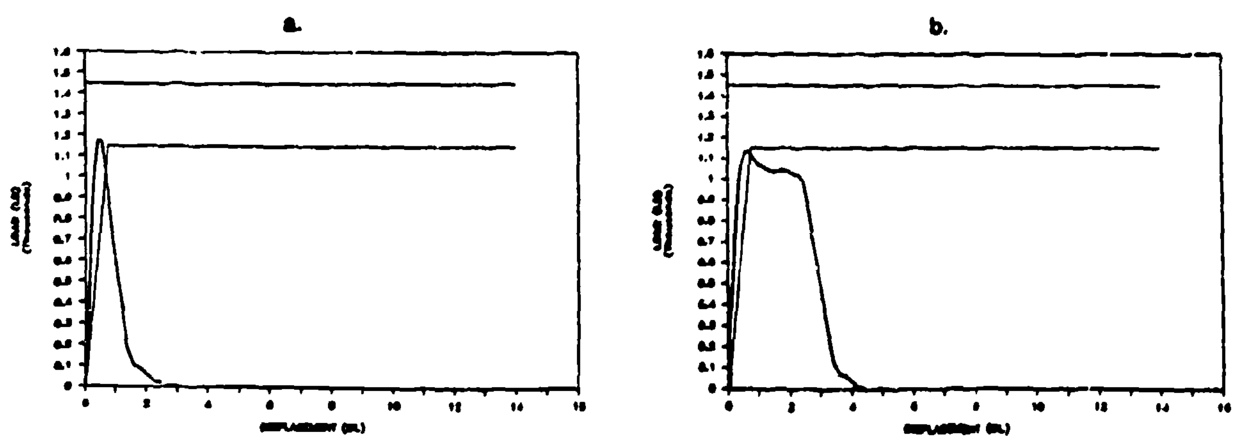

FIGURE B-24. SIKORSKY TROOP SEAT NO. 12, AIRCRAFT T/N 77-22971.

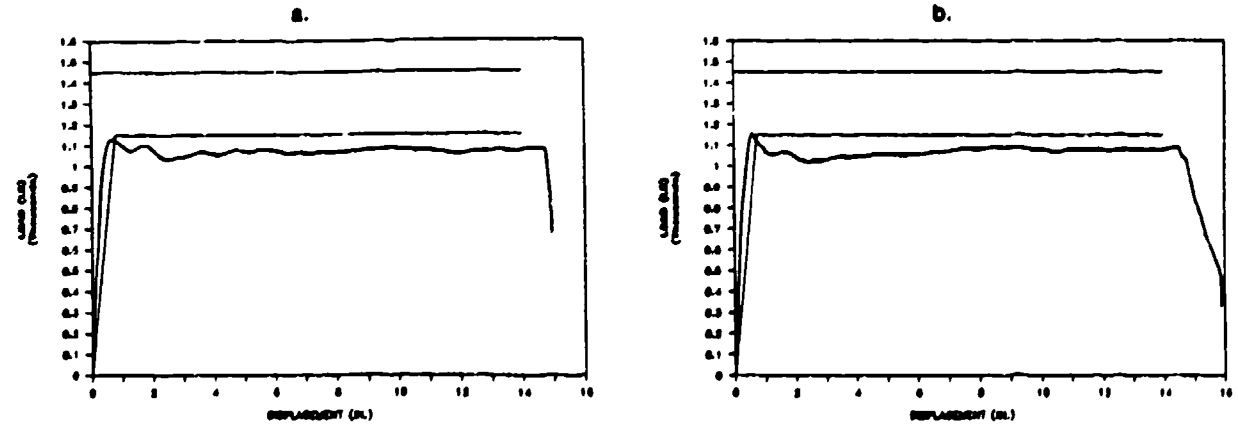

FIGURE B-25. SIKORSKY TROOP SEAT NEW ENERGY ABSORBERS.

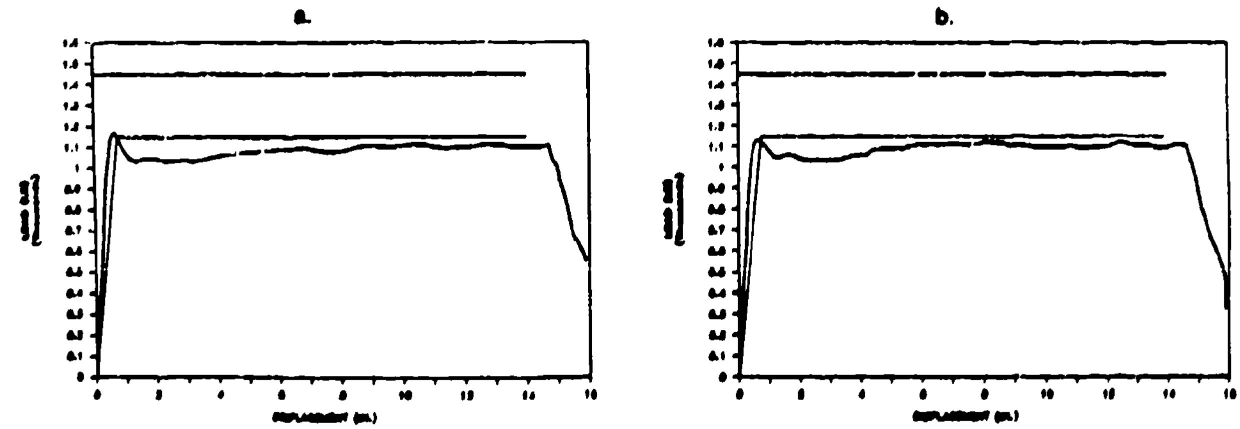

FIGURE B-26. SIKORSKY TROOP SEAT NEW ENERGY ABSORBERS.

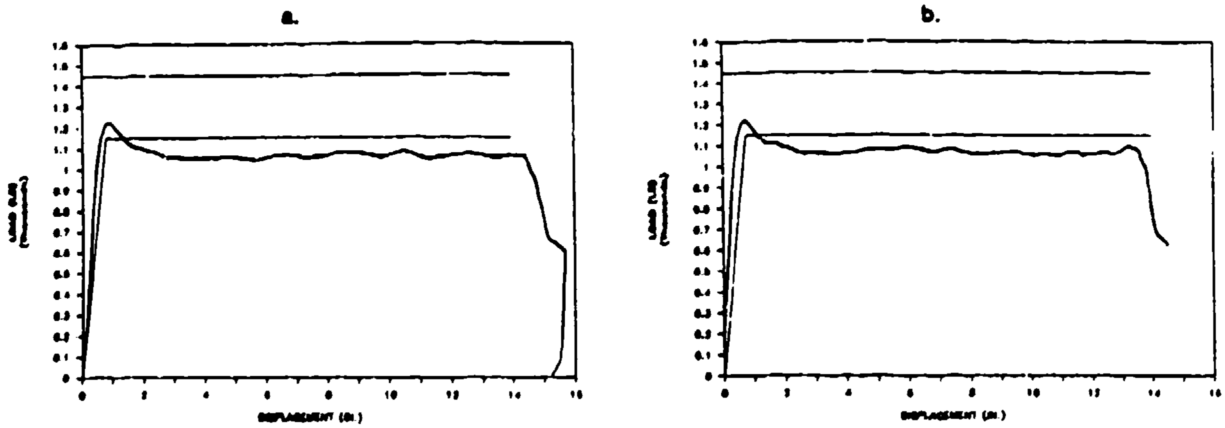

FIGURE B-27. SIKORSKY TROOP SEAT NEW ENERGY ABSORBERS.

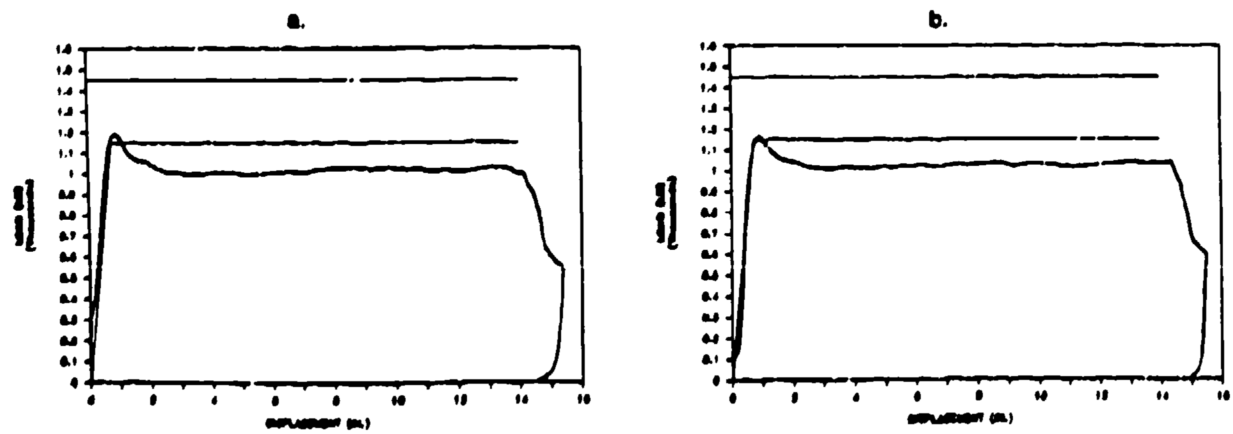

FIGURE B-28. SIKORSKY TROOP SEAT NEW ENERGY ABSORBERS.

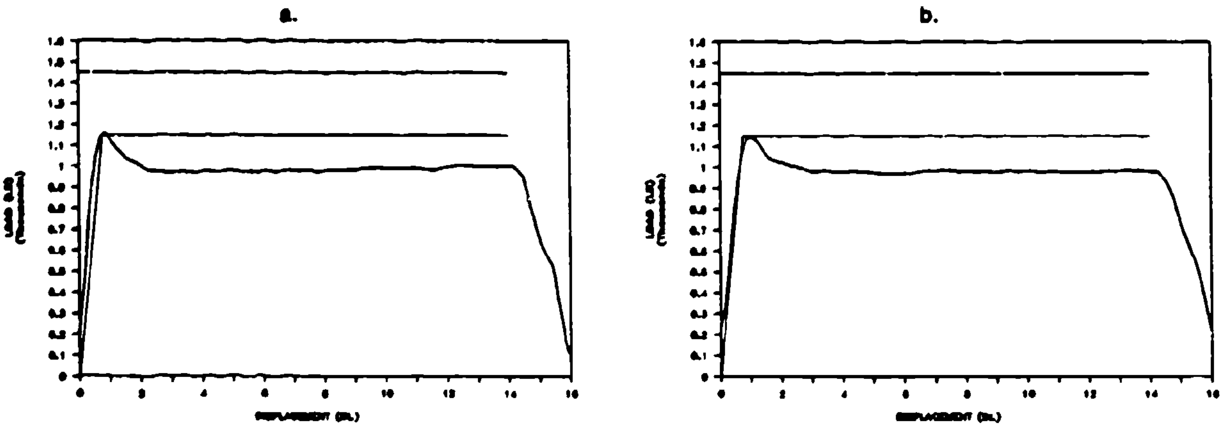

FIGURE B-29. SIKOPSKY TROOP SEAT NEW ENERGY ABSORBERS.

APPENDIX C

ARA CREW SEAT ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS

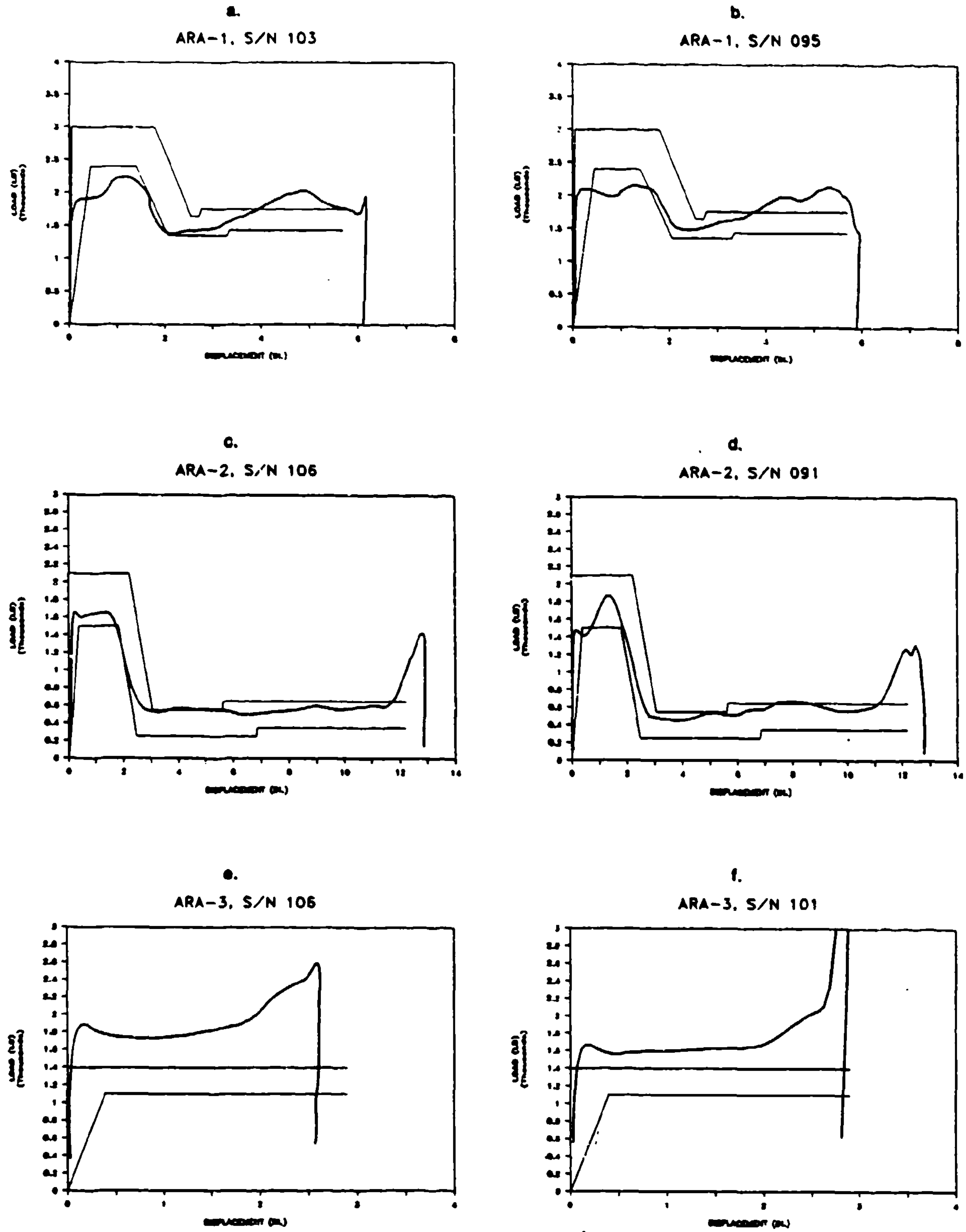

FIGURE C-1. ARA SEAT S/N 031, AIRCRAFT T/N 81-23597.

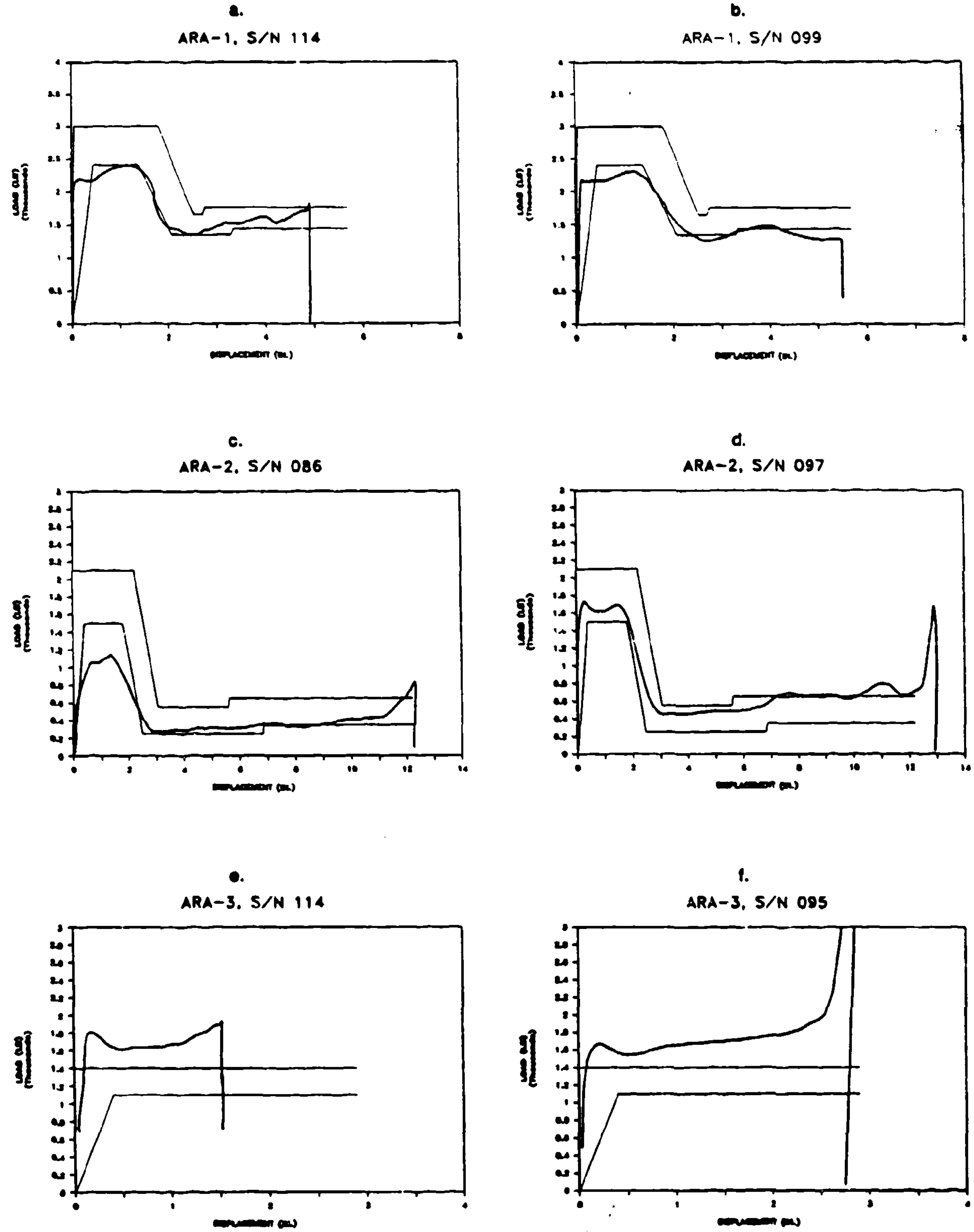

FIGURE C-2. ARA SEAT S/N *, AIRCRAFT T/N 81-23597.

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*Name placard missing.

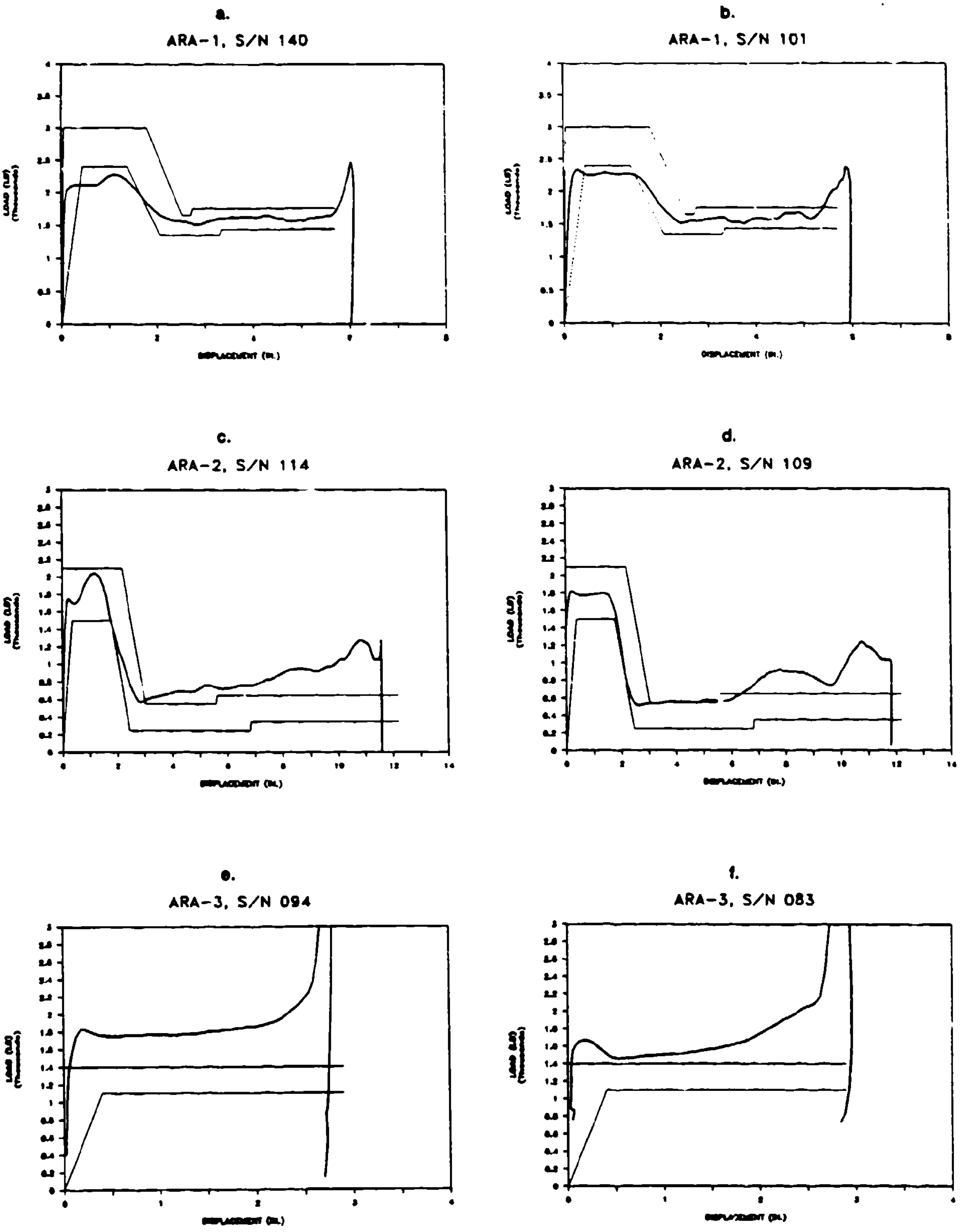

FIGURE C-3. ARA SEAT S/N 043, AIRCRAFT T/N 81-23598.

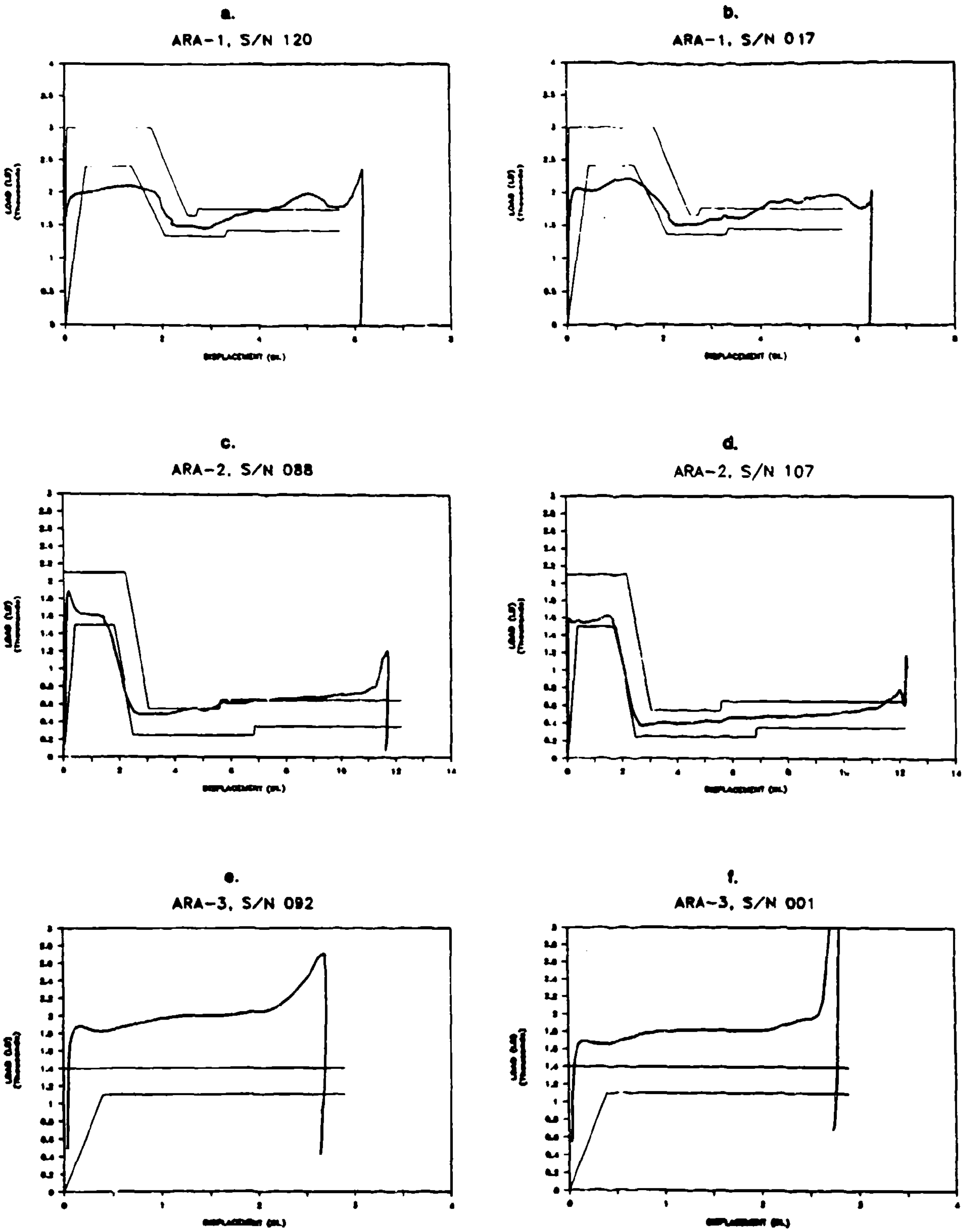

FIGURE C-4. ARA SEAT S/N 042, AIRCRAFT S/N 81-23598.

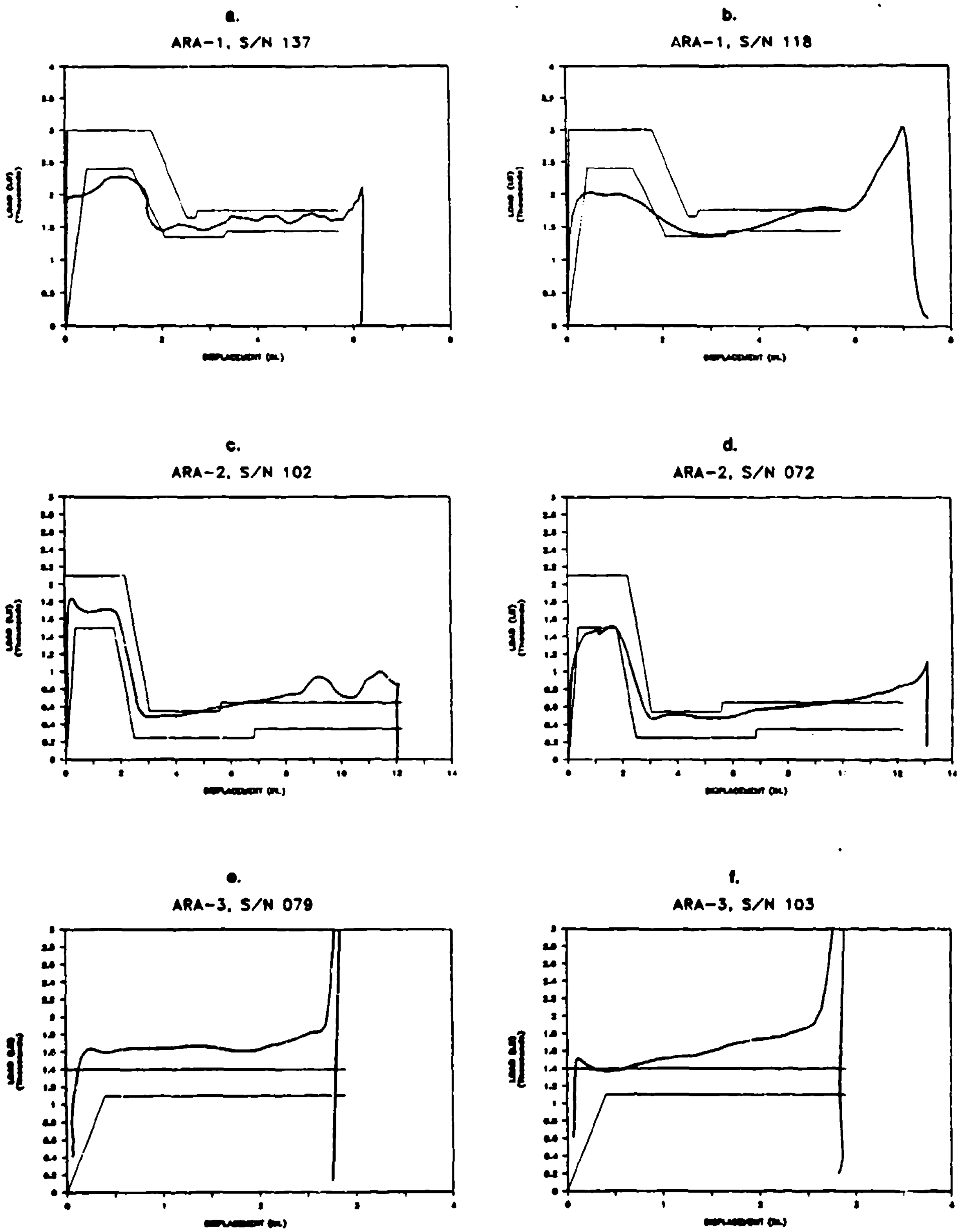

FIGURE C-5. ARA SEAT S/N 046, AIRCRAFT T/N 81-23601.

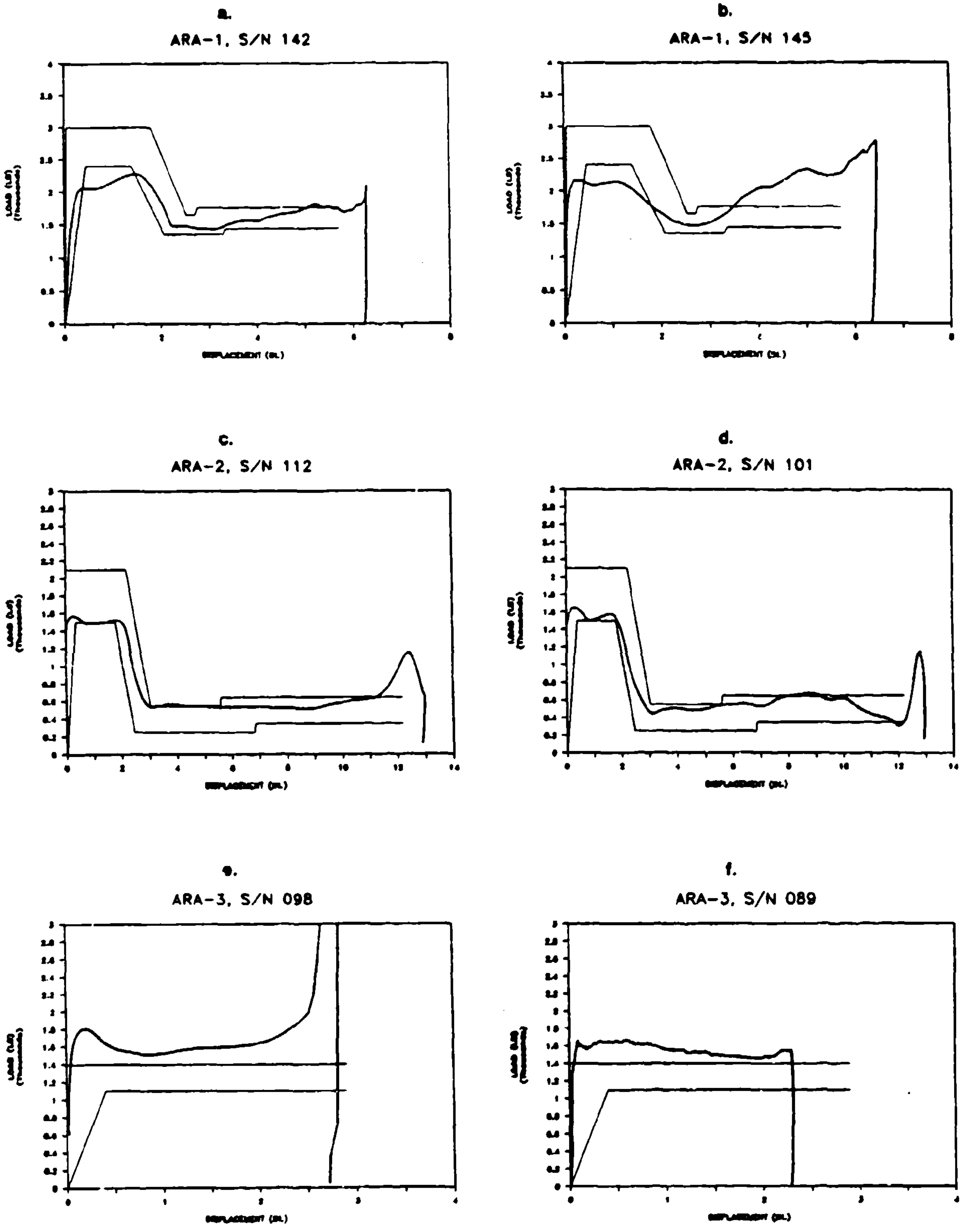

FIGURE C-6. ARA SEAT S/N 045, AIRCRAFT T/N 81-23601.

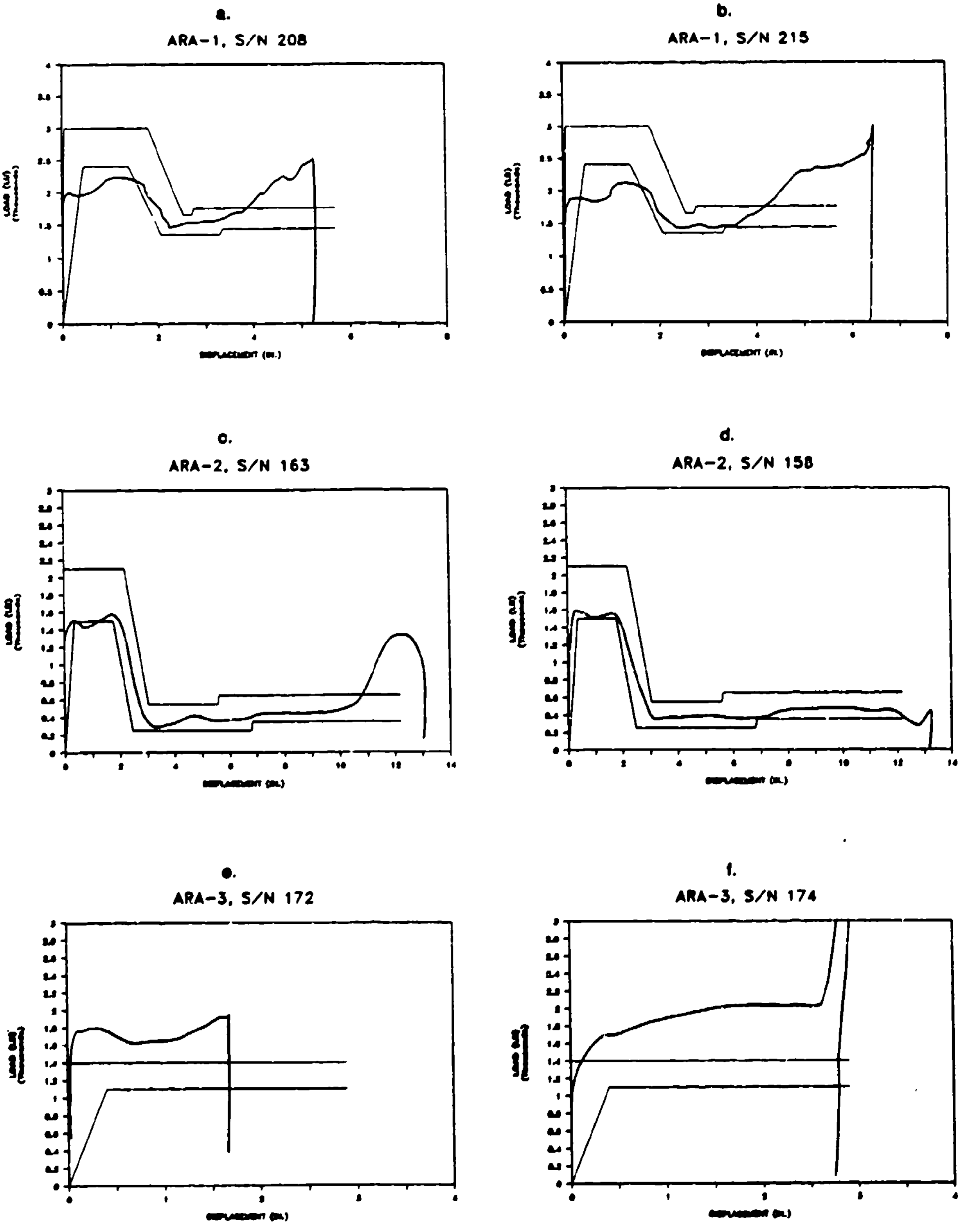

FIGURE C-7. ARA SEAT S/N 081, AIRCRAFT T/N 81-23619.

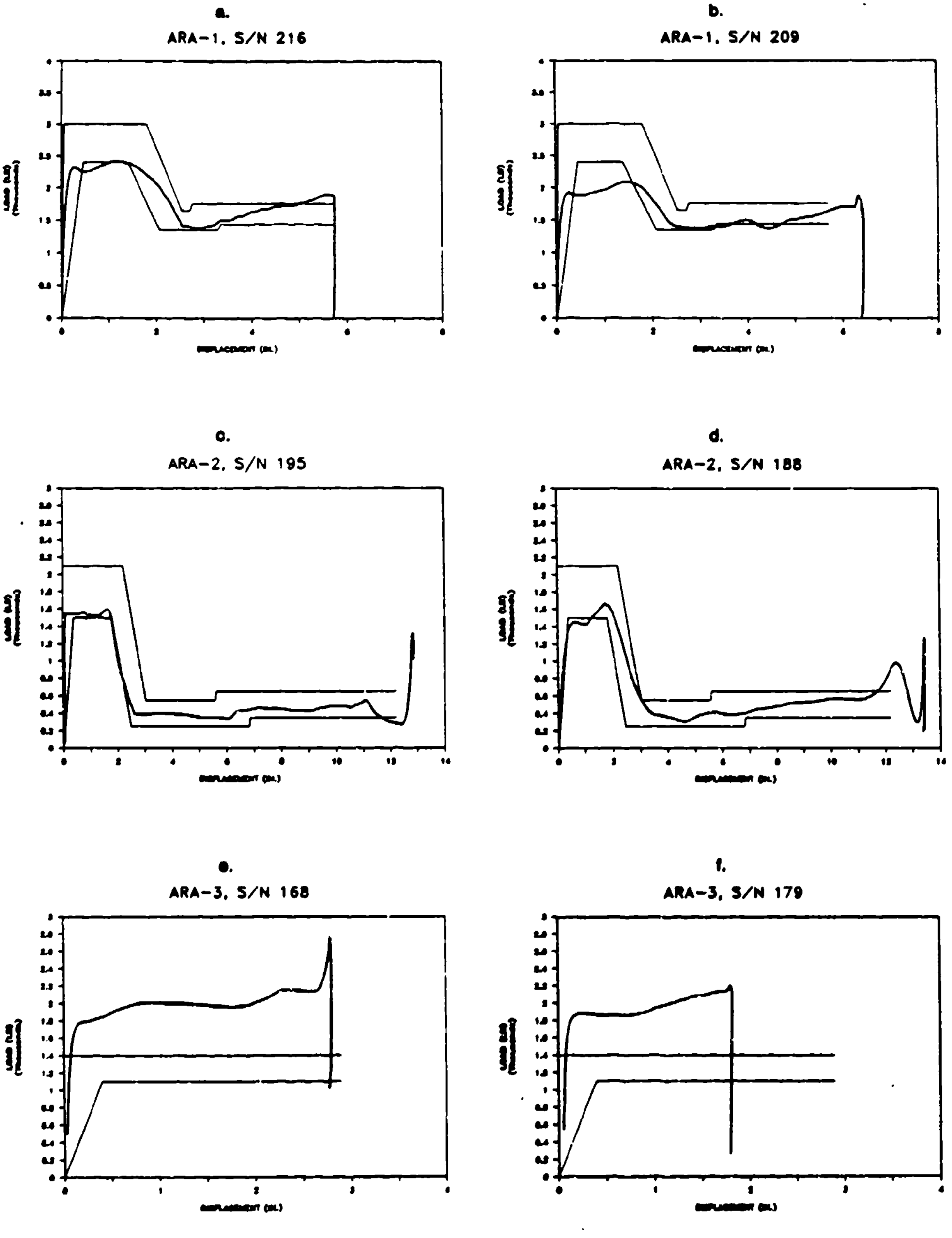

FIGURE C-8. ARA SEAT S/N 077, AIRCRAFT T/N 81-23619.

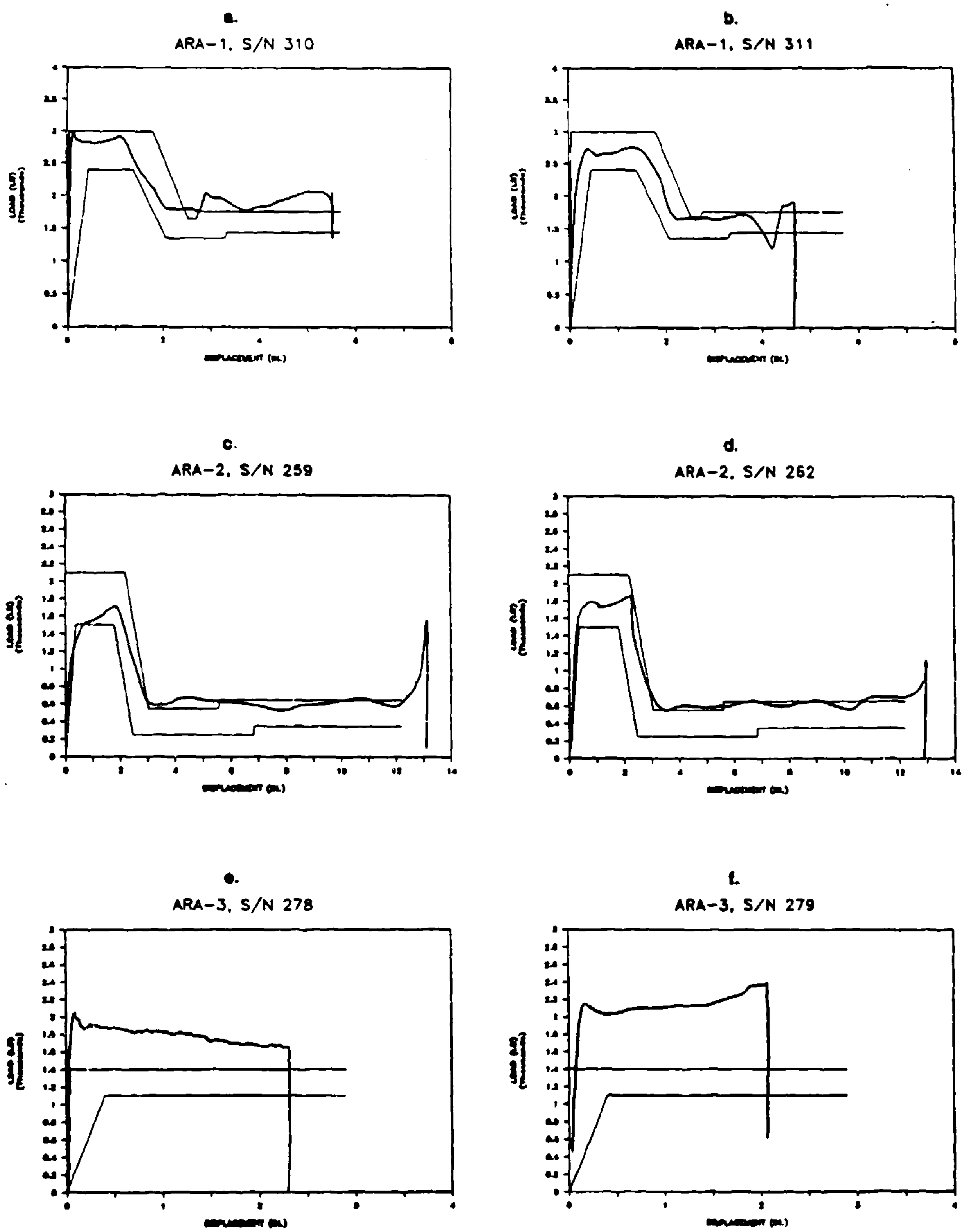

FIGURE C-9. ARA SEAT S/N 126, AIRCRAFT T/N 81-23678.

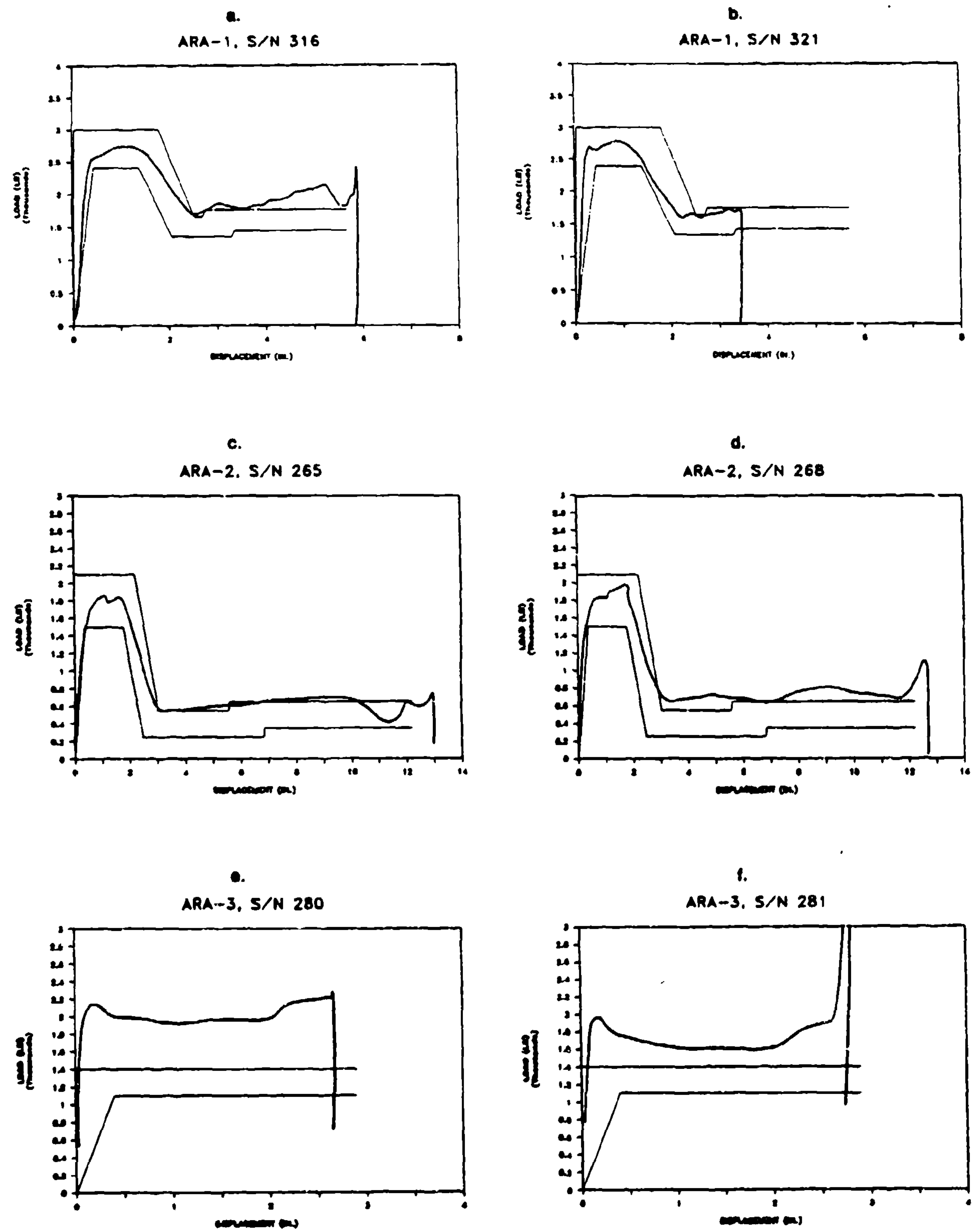

FIGURE C-10. ARA SEAT S/N 128, AIRCRAFT T/N 81-23678.

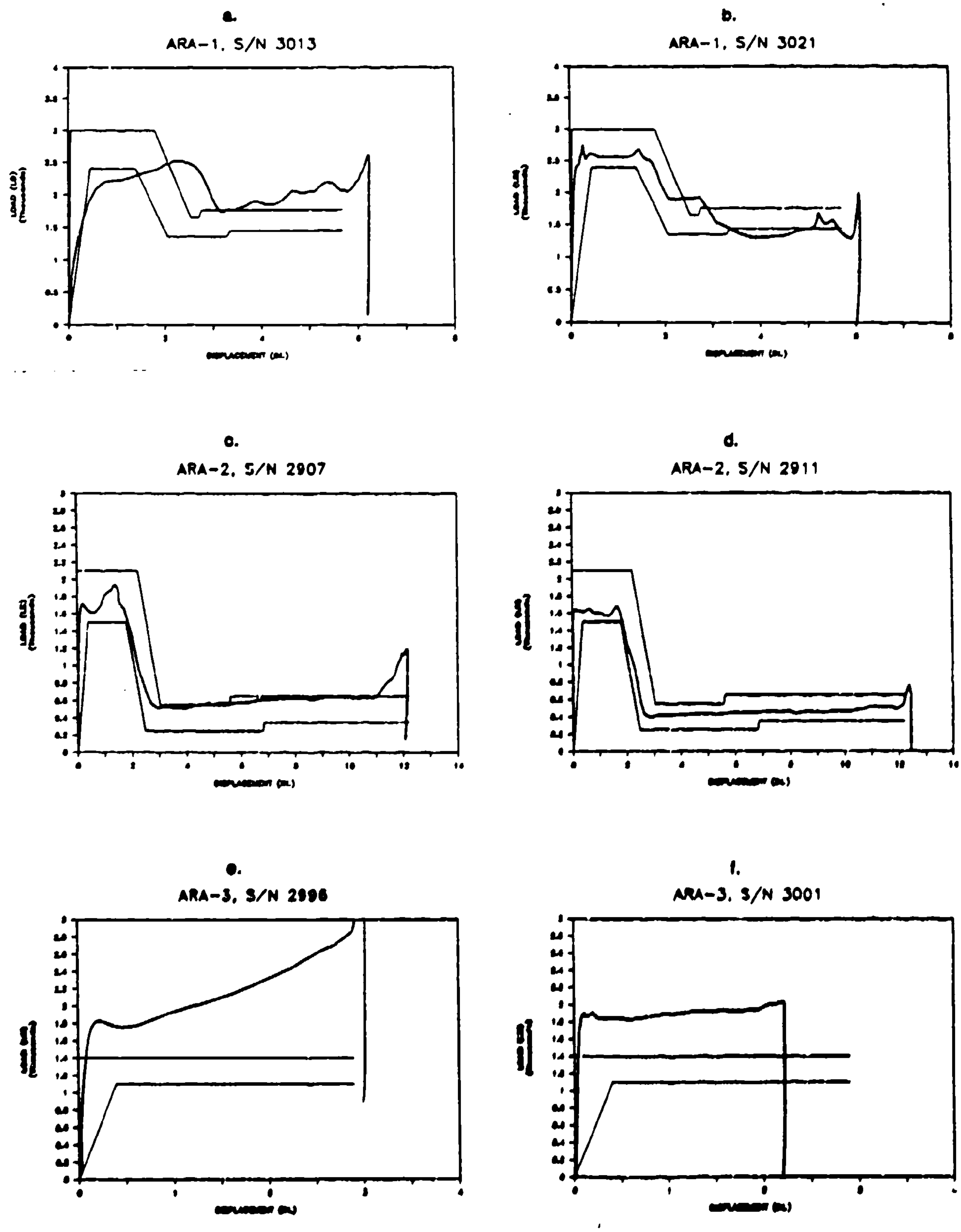

FIGURE C-11. ARA NEW ENERGY ABSORBERS.

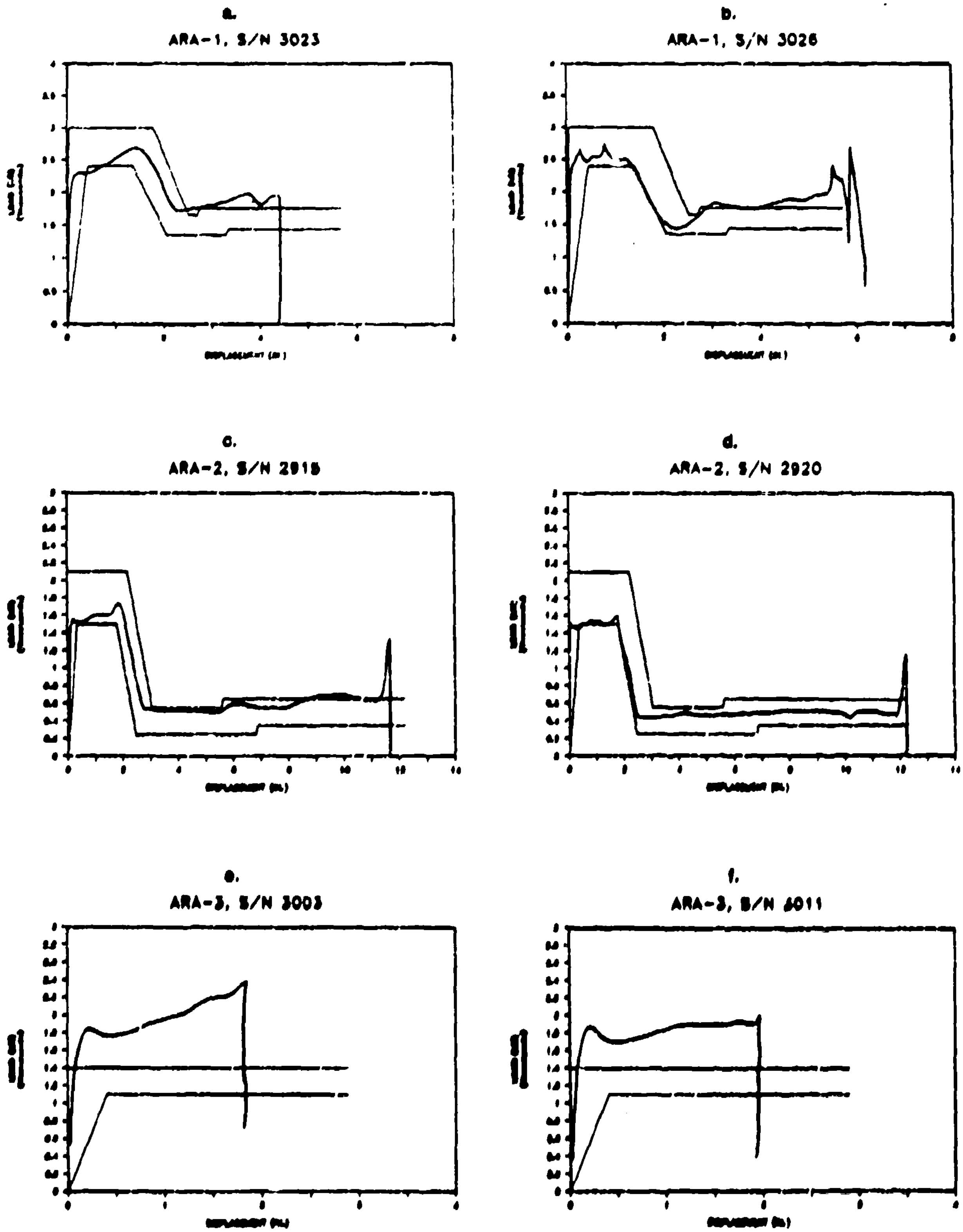

FIGURE C-12. ARA NEW ENERGY ABSORBERS.

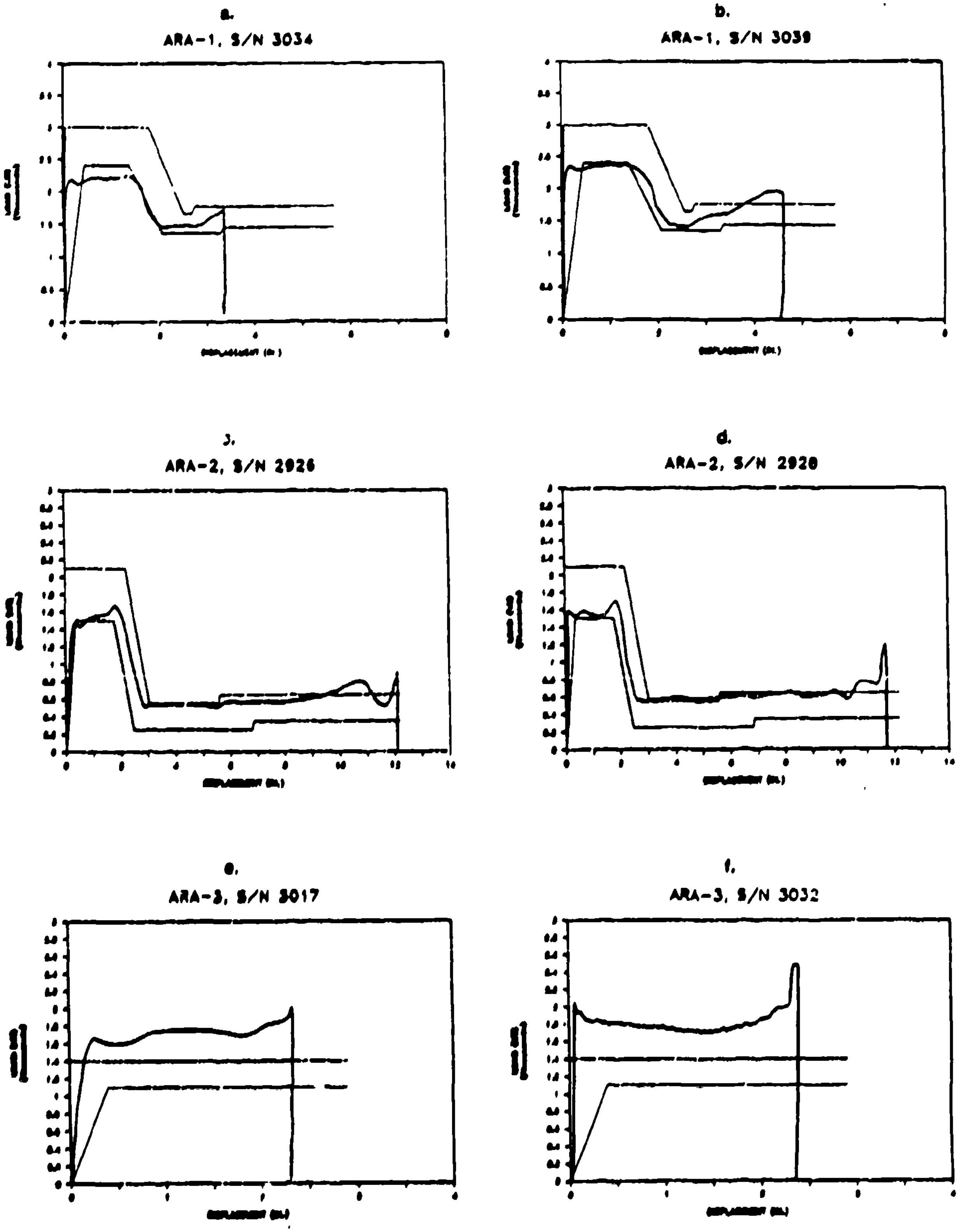

FIGURE C-13. ARA NEW ENERGY ABSORBERS.

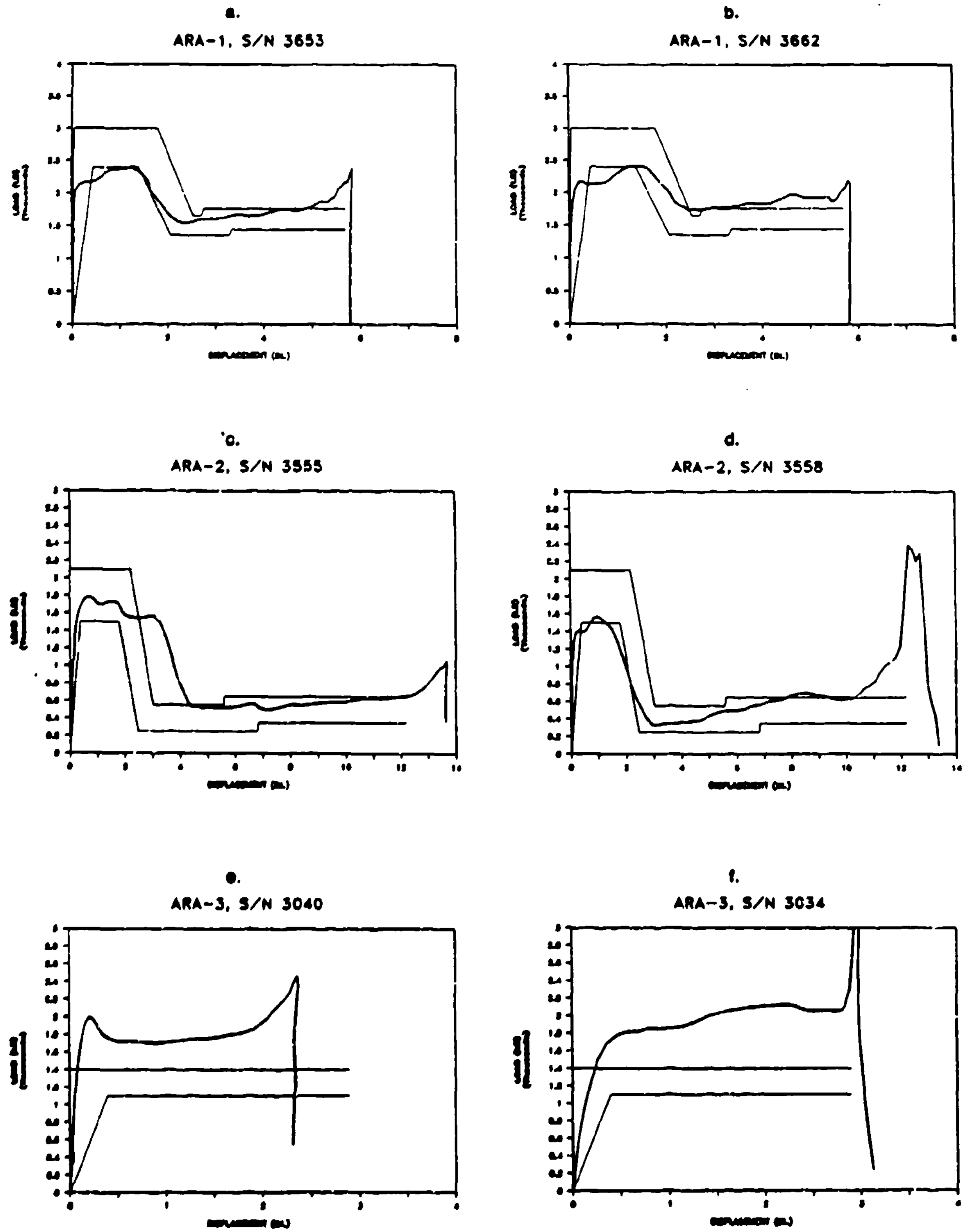

FIGURE C-14. ARA NEW ENERGY ABSORBERS.

APPENDIX D

SIMULA/NORTON CREW SEAT ENERGY ABSORBER LOAD-DEFLECTION CHARACTERISTICS

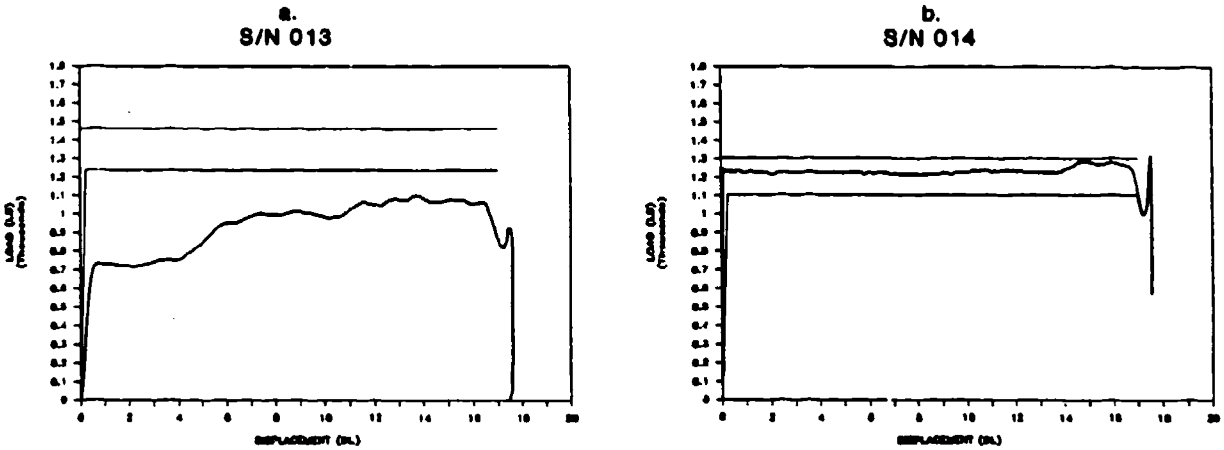

FIGURE D-1. SIMULA/NORTON SEAT S/N 004, AIRCRAFT T/N 77-22728.

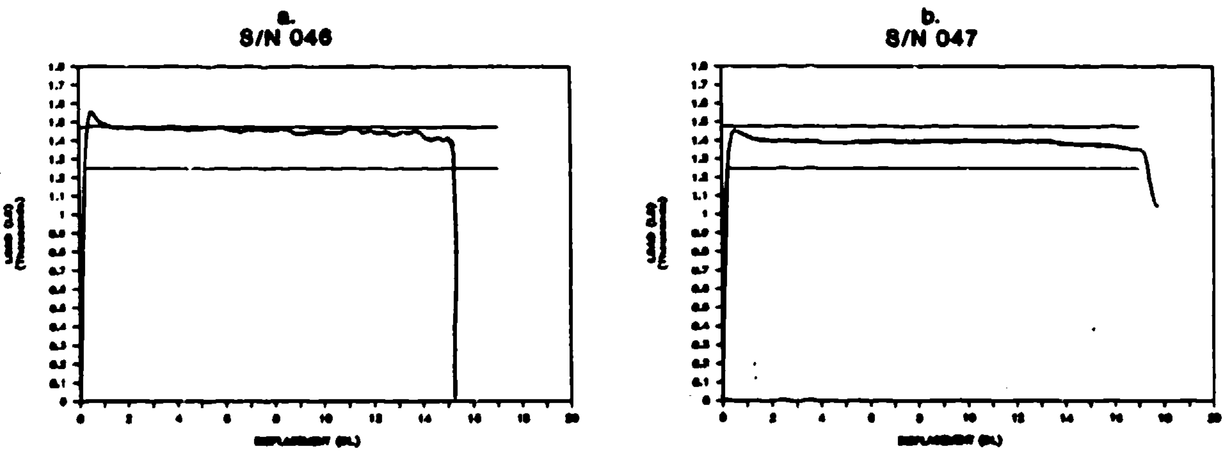

FIGURE D-2. SIMULA/NORTON SEAT S/N 012, AIRCRAFT T/N 77-22728.

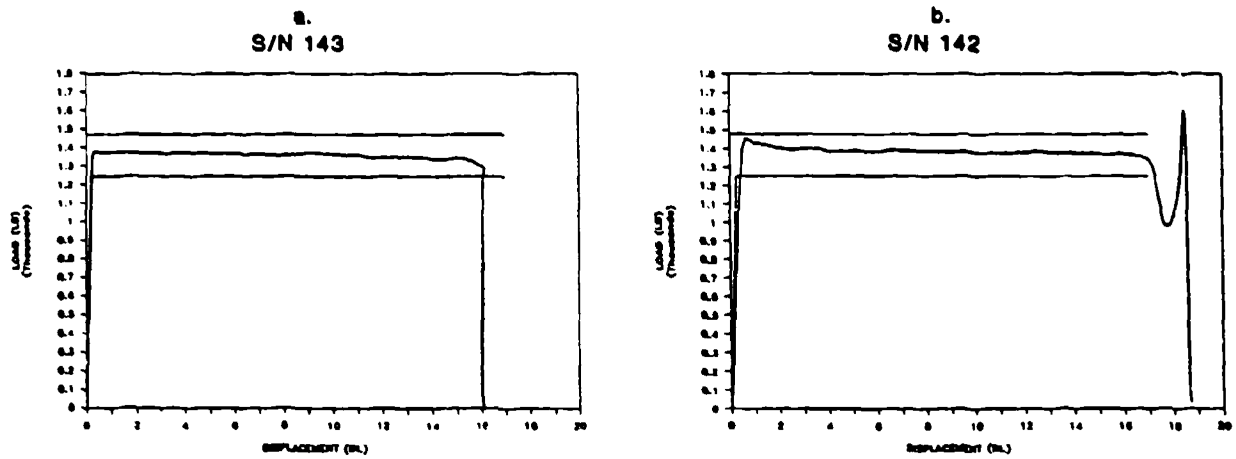

FIGURE D-3. SIMULA/NORTON SEAT S/N 035, AIRCRAFT T/N 78-22966.

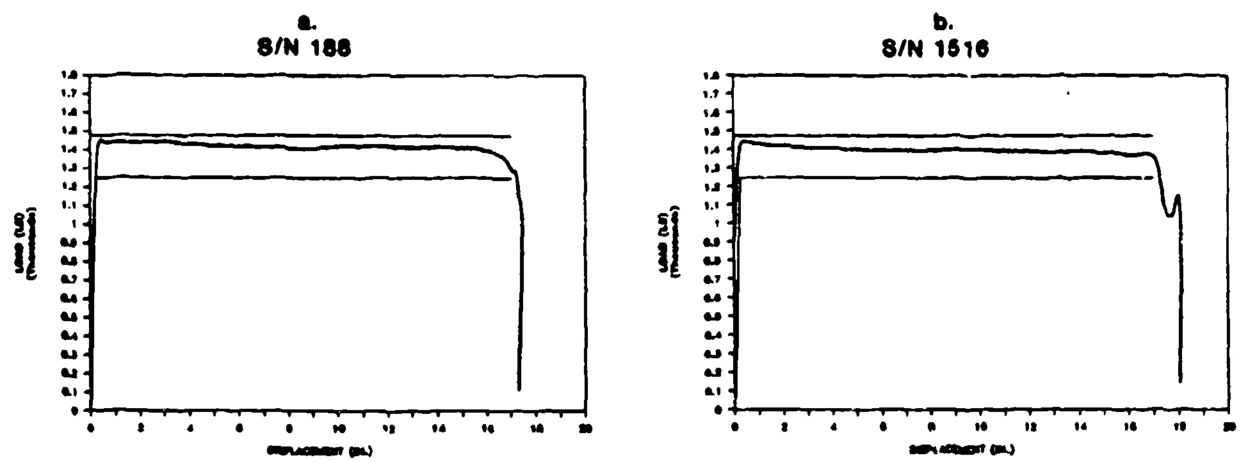

FIGURE D-4. SIMULA/NORTON SEAT S/N 066, AIRCRAFT T/N 78-22966.

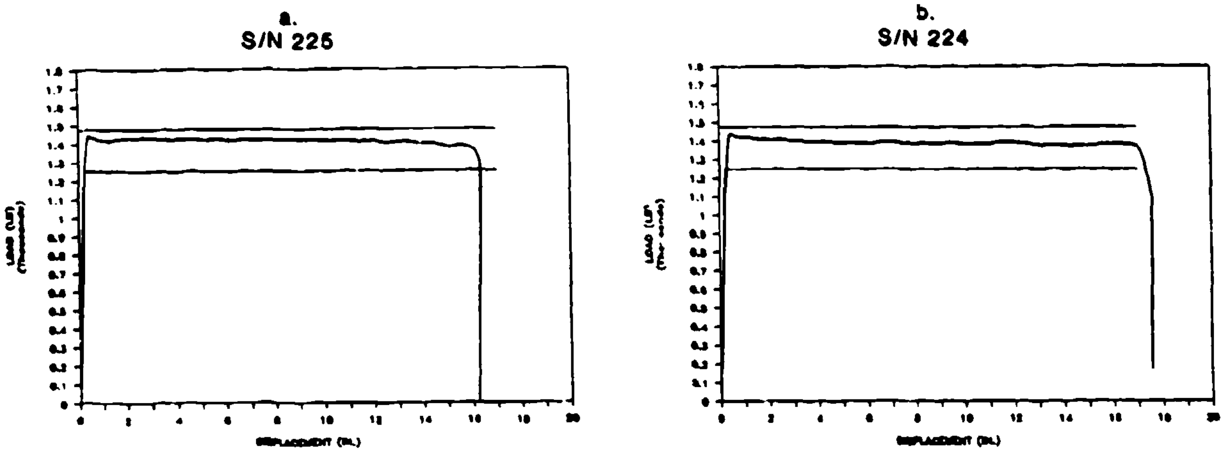

FIGURE D-5. SIMULA/NORTON SEAT S/N 083, AIRCRAFT T/N 78-22973.

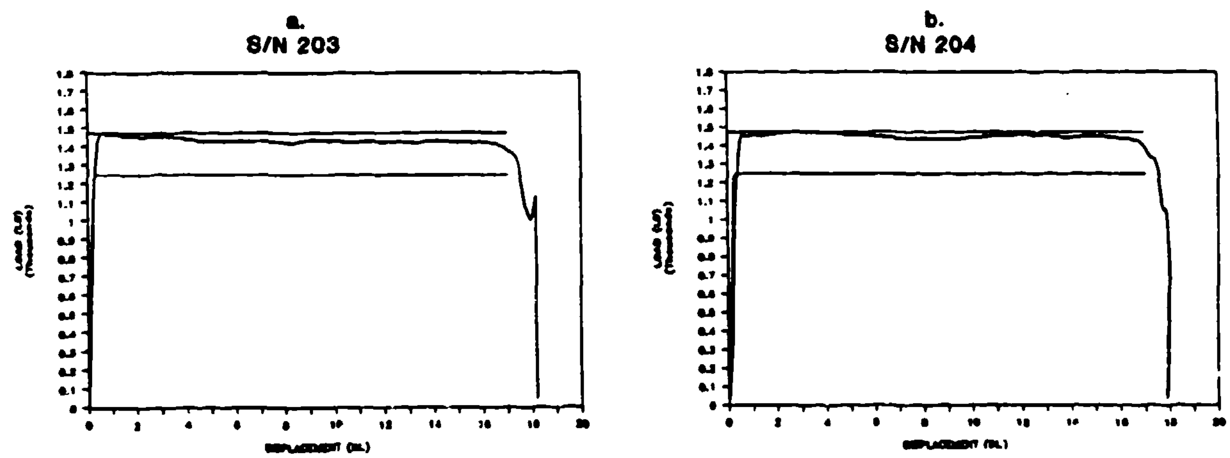

FIGURE D-6. SIMULA/NORTON SEAT S/N 082, AIRCRAFT T/N 78-22973.

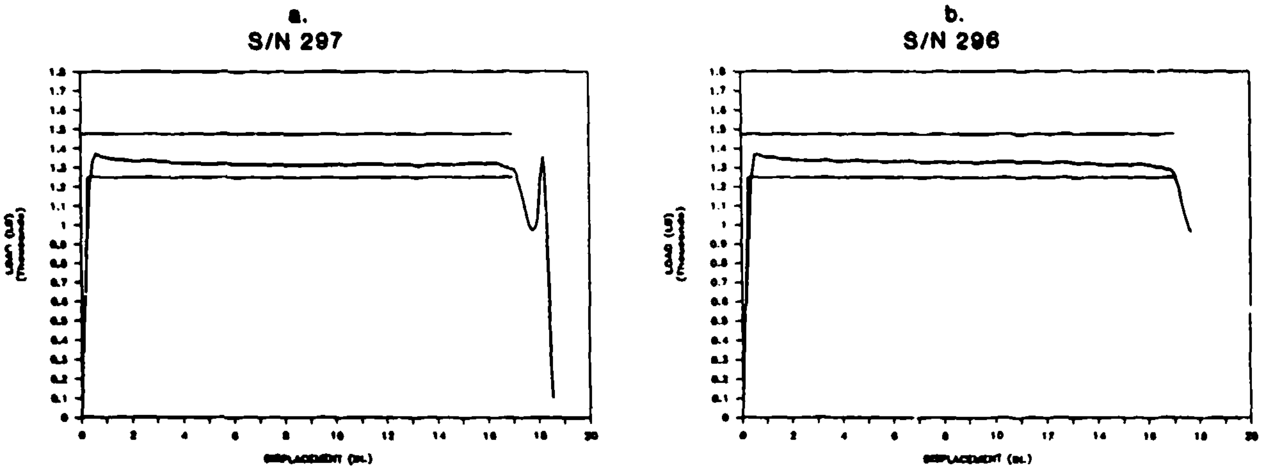

FIGURE D-7. SIMULA/NORTON SEAT S/N 118, AIRCRAFT T/N 78-22990.

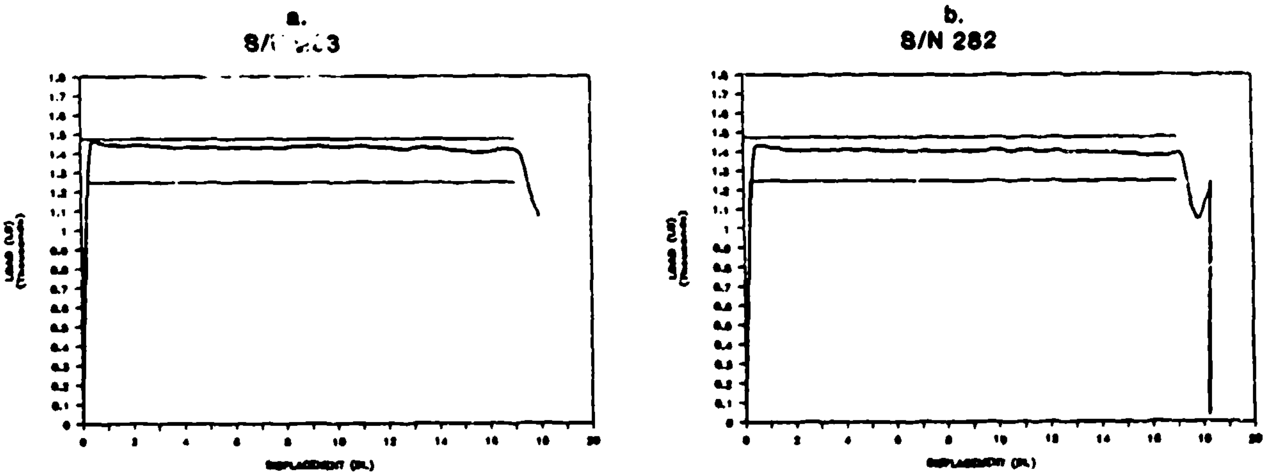

FIGURE D-8. SIMULA/NORTON SEAT S/N *, AIRCRAFT T/N 78-22990.

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*Name placard missing.

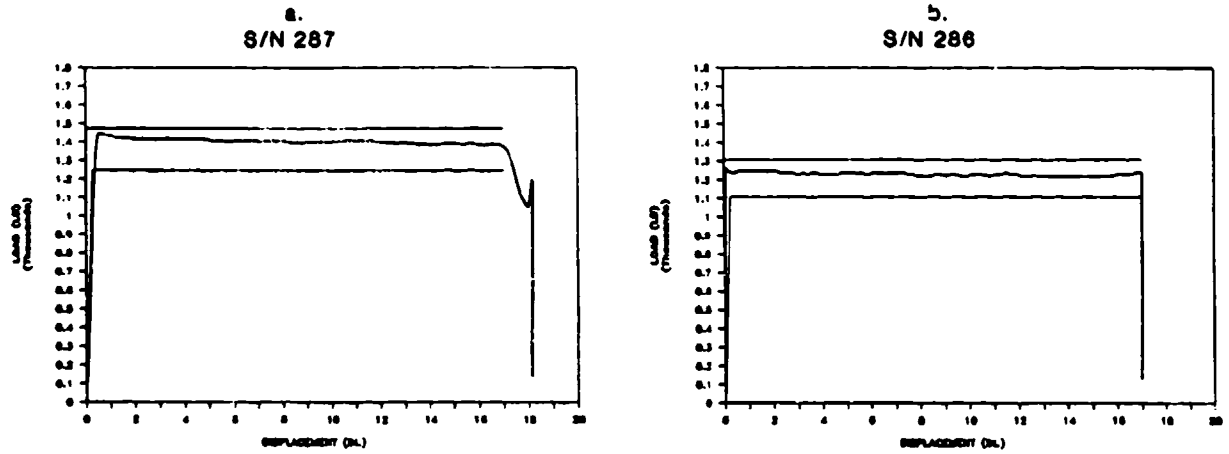

FIGURE D-9. SIMULA/NORTON SEAT S/N 120, AIRCRAFT T/N 78-22991.

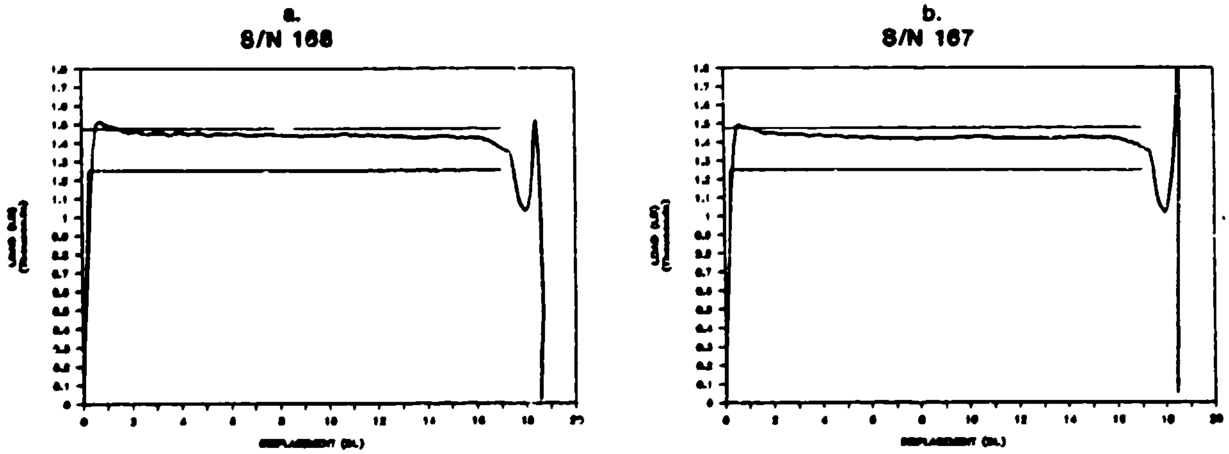

FIGURE D-10. SIMULA/NORTON SEAT S/N 064, AIRCRAFT T/N 78-22991.

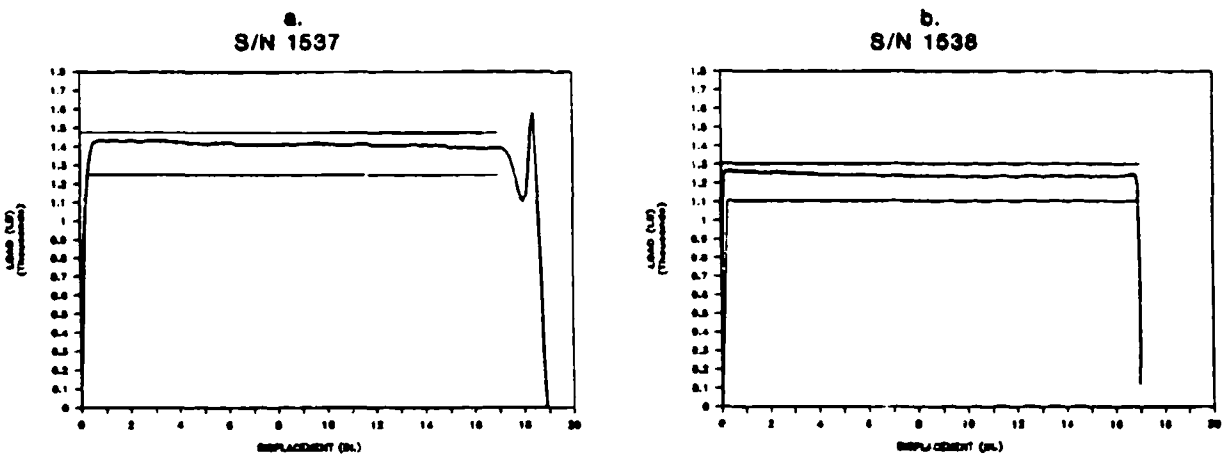

FIGURE D-11. SIMULA/NORTON SEAT NEW ENERGY ABSORBERS.

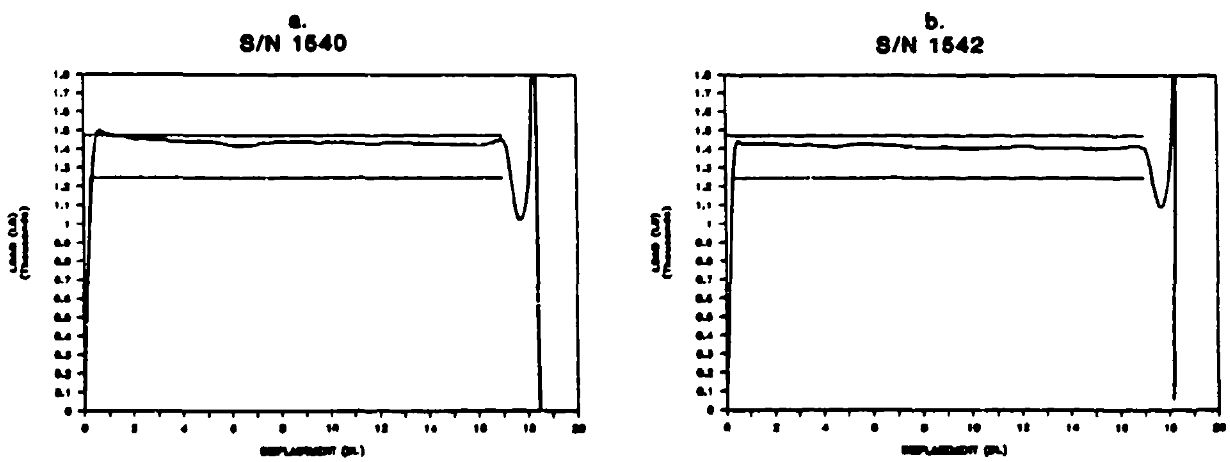

FIGURE D-12. SIMULA/NORTON SEAT NEW ENERGY ABSORBERS.

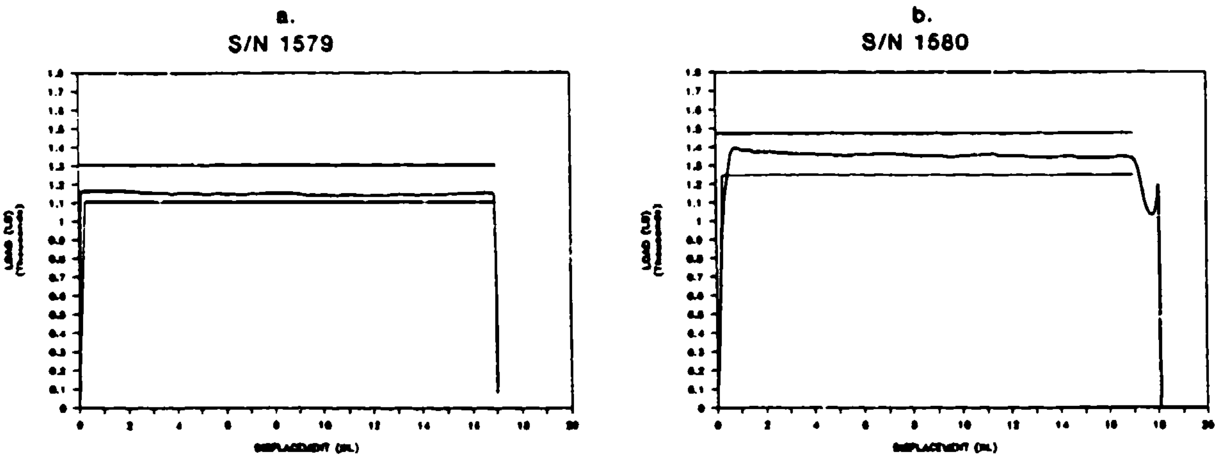

FIGURE D-13. SIMULA/NORTON SEAT NEW ENERGY ABSORBERS.

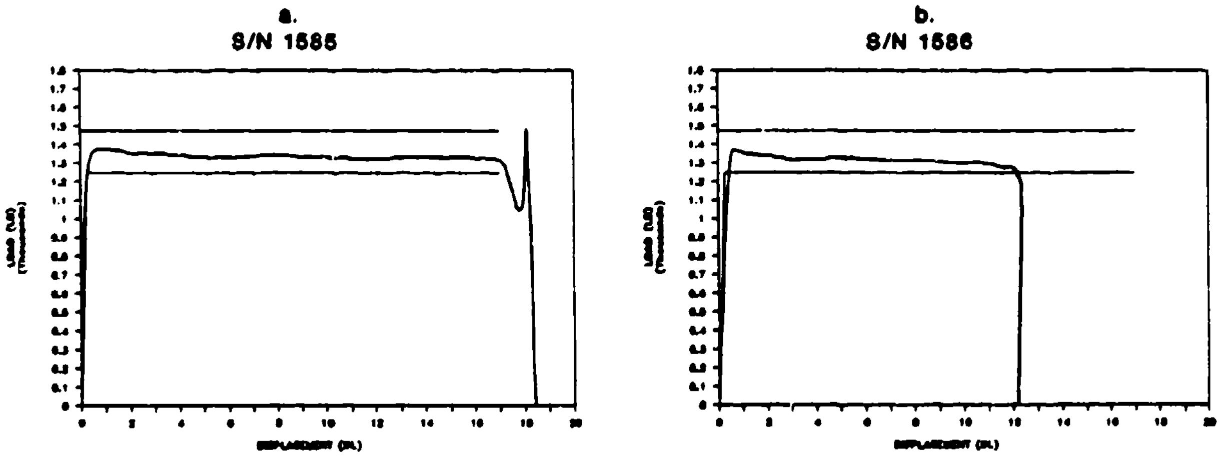

FIGURE D-14. SIMULA/NORTON SEAT NEW ENERGY ABSORBERS.

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